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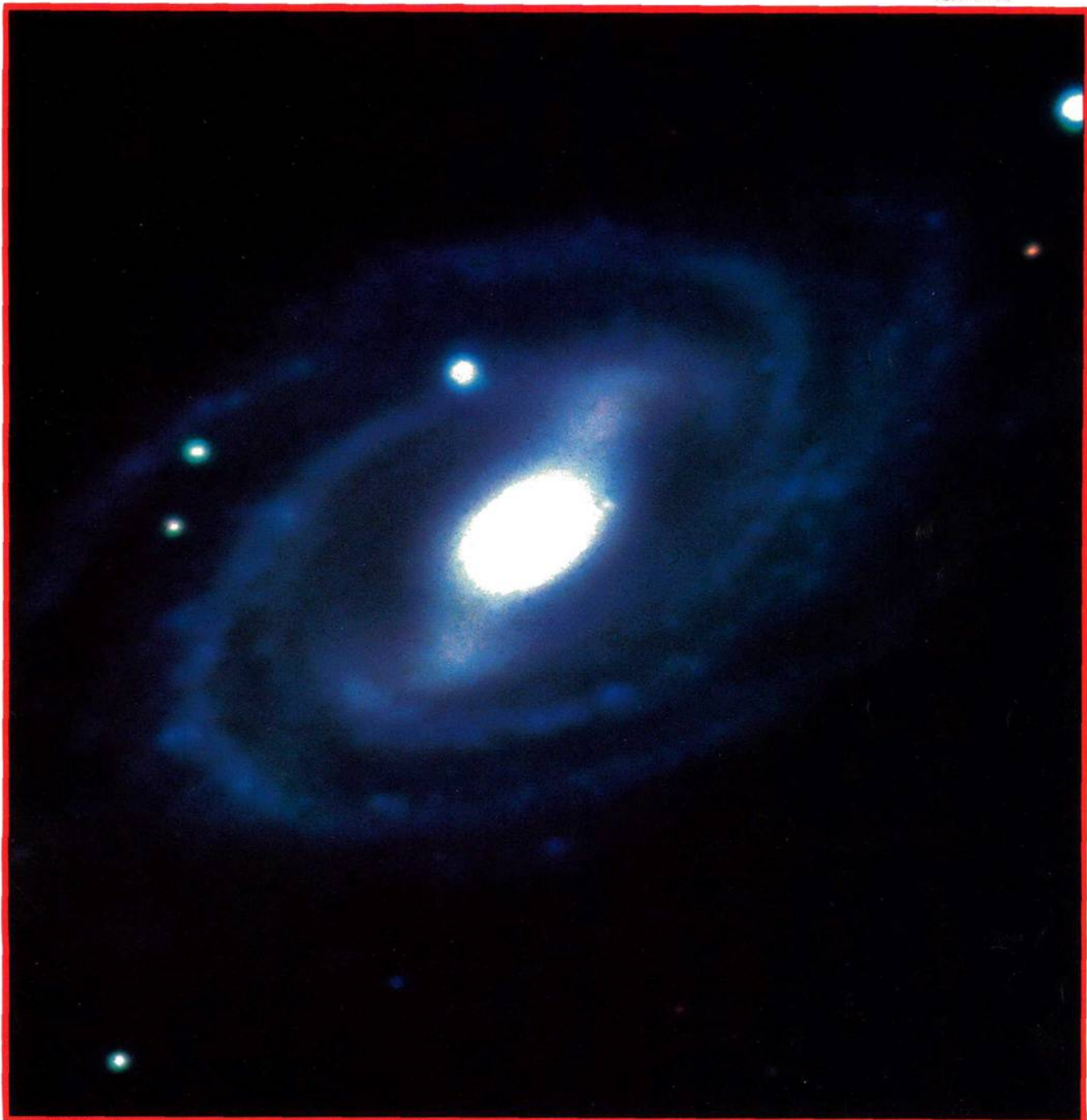
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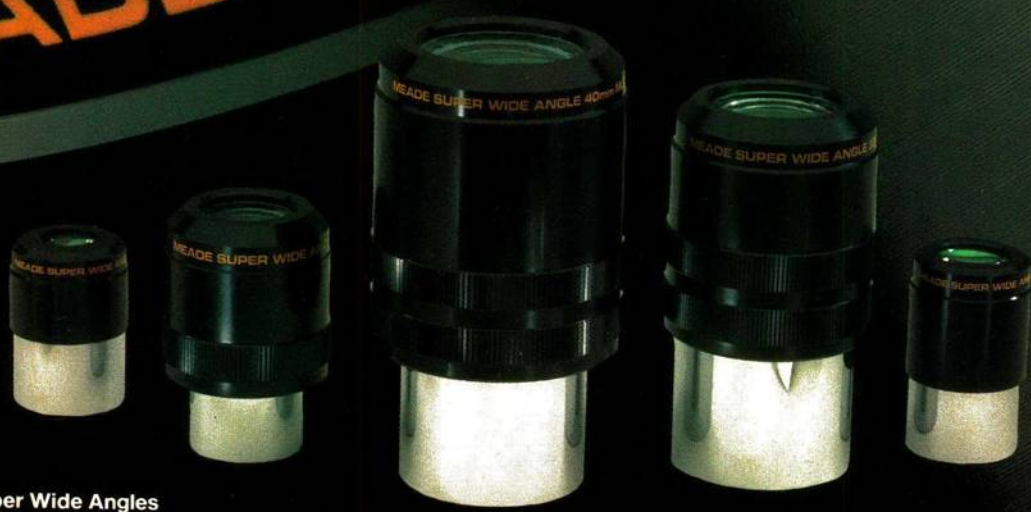


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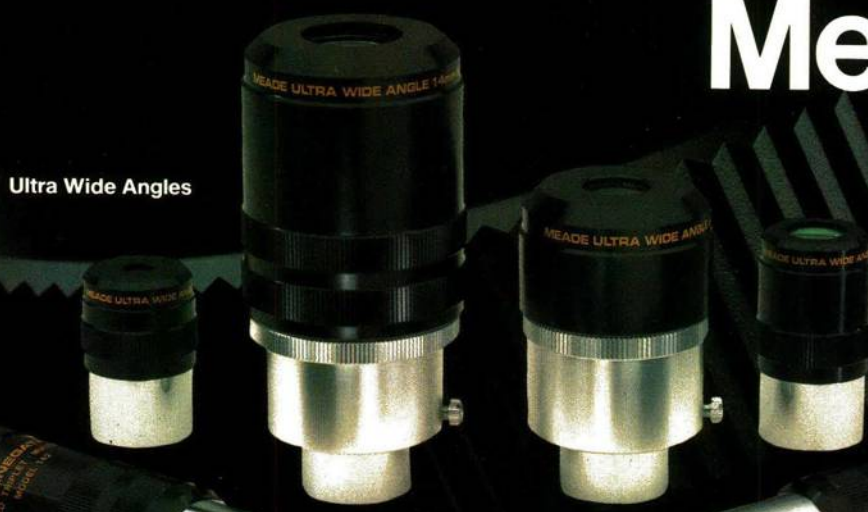




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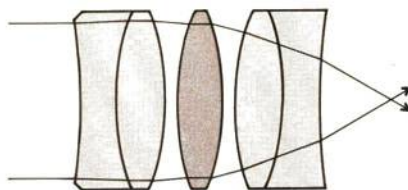
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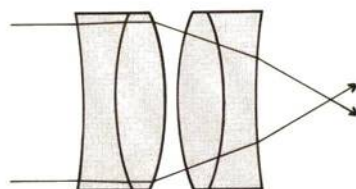
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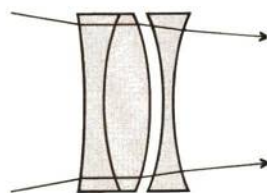
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9.7mm	52°	1 1/4"	Yes
12.4mm	52°	1 1/4"	Yes
15mm	52°	1 1/4"	Yes
20mm	52°	1 1/4"	Yes
26mm	52°	1 1/4"	Yes
32mm	52°	1 1/4"	Yes
40mm	44°	1 1/4"	No
56mm	52°	2"	No

Super Wide Angles (6-elements)

13.8mm	67°	1 1/4"	Yes
18mm	67°	1 1/4"	Yes
24.5mm	67°	1 1/4"	Yes
32mm	67°	2"	No
40mm	67°	2"	No

Ultra Wide Angles (8-elements)

4.7mm	84°	1 1/4"	Yes
6.7mm	84°	1 1/4"	Yes
8.8mm	84°	1 1/4" & 2"	Yes
14mm	84°	1 1/4" & 2"	No

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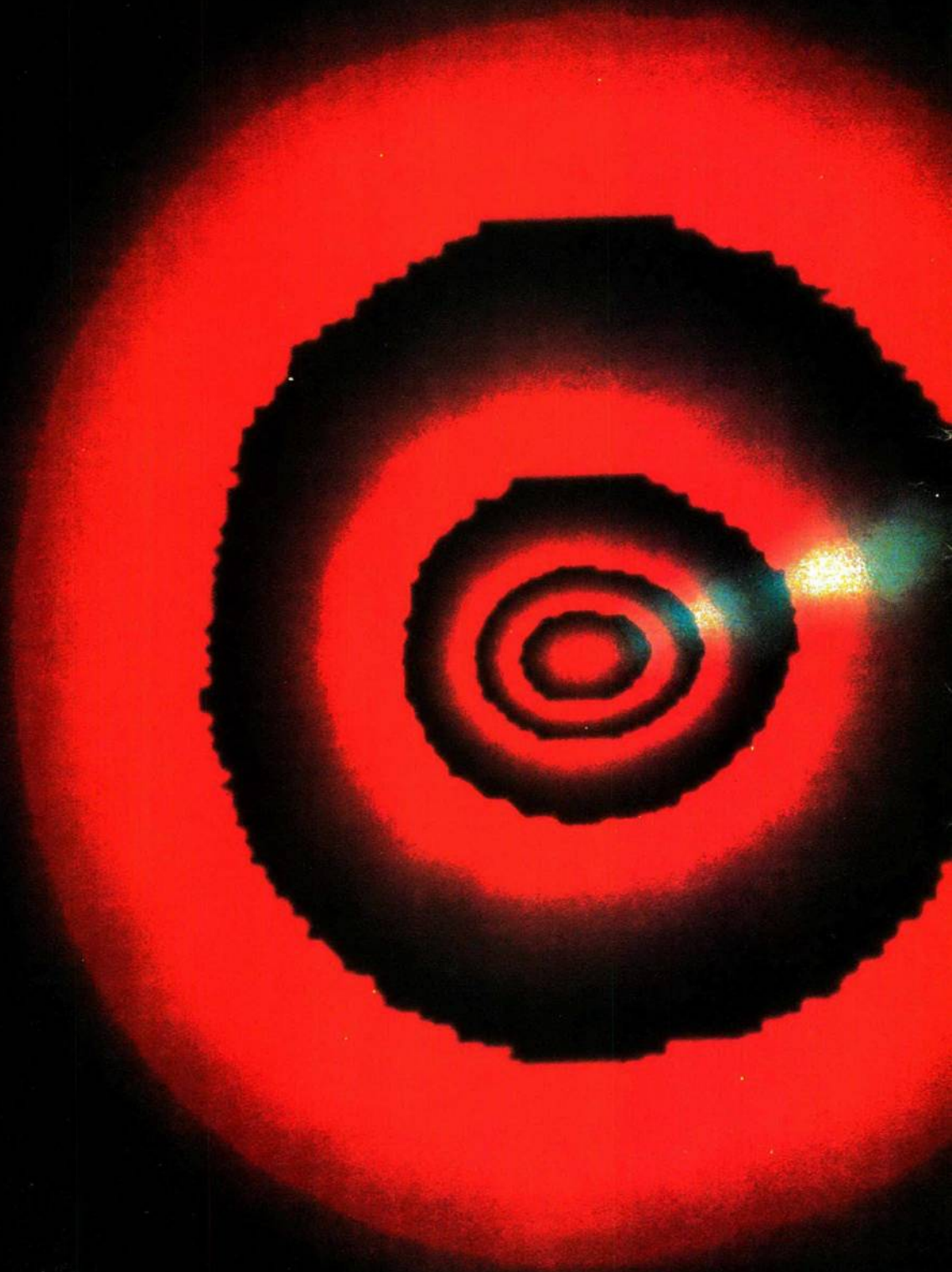
Cover: The graceful swirling arms of spiral galaxies, like M-109, betray a violent presence in many galaxies: supermassive black holes. This month ASTRONOMY takes you into a realm of relativistic cosmology that has a profound effect on certain spots in the universe. Photo courtesy Rudolph Schild, Smithsonian Astrophysical Observatory. These pages: Planes and stars criss-cross the sky in an unguided exposure by a "dilettante" astrophotographer. Photo by John C. Waugh.

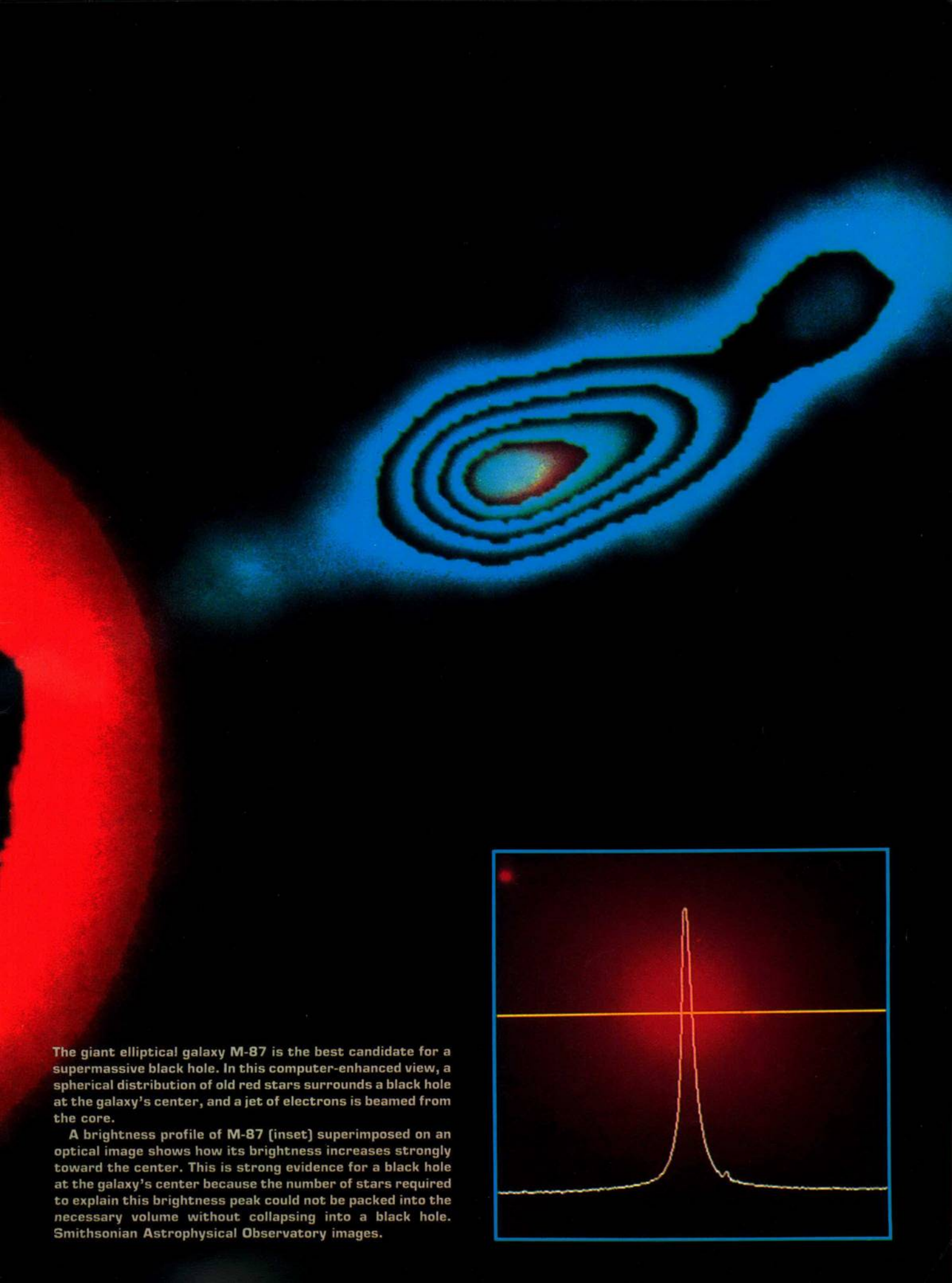
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IN AND AROUND BLACK HOLES

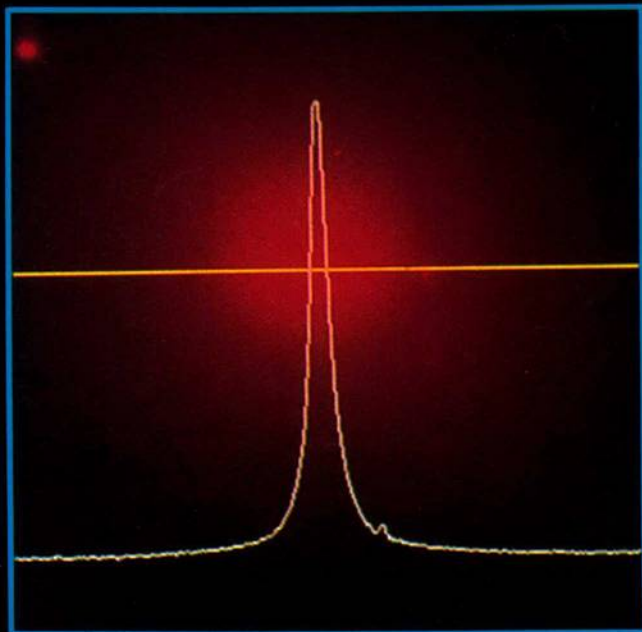
by Barry Parker



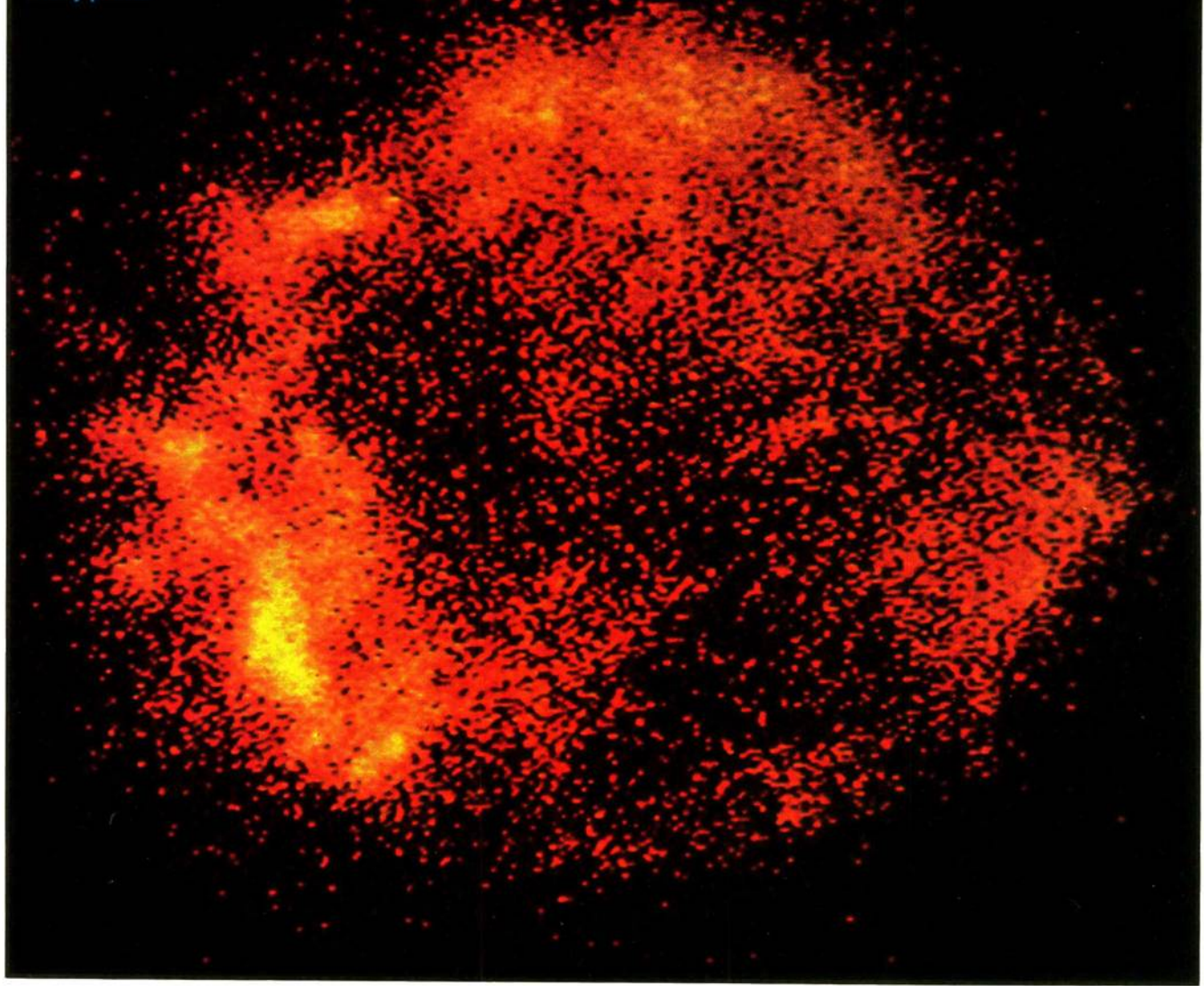


The giant elliptical galaxy M-87 is the best candidate for a supermassive black hole. In this computer-enhanced view, a spherical distribution of old red stars surrounds a black hole at the galaxy's center, and a jet of electrons is beamed from the core.

A brightness profile of M-87 (inset) superimposed on an optical image shows how its brightness increases strongly toward the center. This is strong evidence for a black hole at the galaxy's center because the number of stars required to explain this brightness peak could not be packed into the necessary volume without collapsing into a black hole. Smithsonian Astrophysical Observatory images.



The supernova remnant Cassiopeia A is shown here in an x-ray image taken by the Einstein Observatory. Collapsed objects often form following a supernova explosion and some of these may be black holes. Despite detailed studies, however, no collapsed object has yet been found at the center of this supernova remnant. Whether the original star completely destroyed itself or is now a dim neutron star or black hole is unknown. Smithsonian Astrophysical Observatory photo.



Black holes are extraordinary objects that require our familiar notions of space and time to take on bizarre new properties. Although a host of possible black holes have tentatively been identified in space, there is as yet no unequivocal proof that black holes exist on more than a theoretical basis.

Our current conception of black holes is based on Albert Einstein's general theory of relativity, which was first published in 1916. The theory was an elegant new look at nature formulated in the mathematical language of tensor analysis. The equations within the theory describe the structure of space that arises from a given distribution of matter. The solutions to these equations were complicated enough, however, that Einstein did not pursue them.

The first mathematical solution came from the German astronomer Karl Schwarzschild, who was a volunteer serving on the Russian front during World War I.

Schwarzschild was suffering from a rare metabolic disorder and was in a weakened state when he received a copy of Einstein's theory. Nevertheless he began working on the equations and within a short time arrived at a solution for a spherical distribution of matter. He sent the solution to Einstein who was immensely pleased with it.

"I have read your paper with great interest," Einstein wrote back. "I had not expected that the exact solution of the problem would be formulated so simply. . . . I will present the work . . . to the academy."

But Schwarzschild's condition continued to deteriorate, and within a few months after receiving the letter he was dead. His solution to Einstein's equations, however, has lived on and is still one of the most important solutions. It describes the curvature of space around a star, or any spherical mass, but it also describes an extremely strange object, one that has all its mass at a point — an object we now call a black hole.

Although Einstein was pleased with Schwarzschild's solution, he was disturbed to discover that it predicted a bizarre region of space. Examining the details of the solution he saw that surrounding an immeasurably small point of infinite density — what physicists call a singularity — was a surface that was seemingly cut off from the rest of our universe. If you passed through this surface you could never return. We now refer to it as the event horizon because it marks the boundary beyond which any event would be impossible to observe. The distance from the event horizon to the singularity is known as the Schwarzschild radius.

Einstein struggled for several years to show that black holes couldn't exist, but he never succeeded. And in 1939 Robert Oppenheimer and Hartland Snyder showed that, indeed, they could occur when a star died. If the star was massive enough (greater than about 3 solar masses) it would collapse forever and become a black hole.

Varieties of Black Holes

The first and simplest type of black hole, the kind that occurs in the collapse of a perfectly spherical star, is called a Schwarzschild black hole, in honor of Karl Schwarzschild. Astronomers soon became interested in whether there were other solutions to Einstein's equations, and hence other types of black holes. They found that this depended on what properties were left when a star collapsed and became a black hole. A different type of black hole could only arise from different properties in the original star.

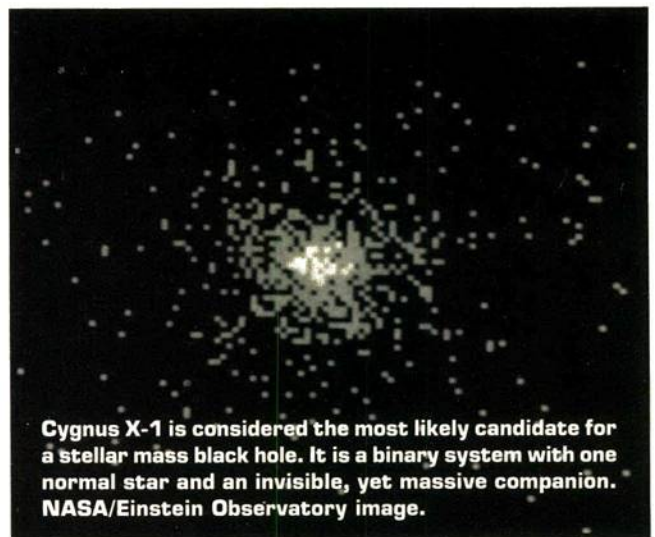
Most of a star's properties, however, are lost when the matter of the star is crushed and it becomes a black hole. One property that isn't lost, of course, is mass. We know how massive the star was because the black hole has a gravitational field that astronomers can measure through its effect on other objects. The strength of the gravitational field depends on how much mass is creating it.

What happens to the star's other properties? Since gravity is able to extend beyond the event horizon, perhaps there are other forces in nature that are also able to do this. One such force is the electromagnetic field caused by electric charge. If the star had a charge before the collapse, it will have the same charge after the collapse.

The mathematical solution to Einstein's field equations for the case of a charged black hole was discovered by Reissner and Nordstrom between 1916 and 1918. In nature, though, as we shall see, it is unlikely that charged black holes are common. If an excess of positive or negative charge accumulates on a star, it is usually quickly neutralized — positive charge attracts negative charge and vice versa. Therefore, if a black hole begins with a charge it is small, and it would subsequently be further reduced by the process of neutralization.

Are there any other properties that are not lost down the black hole? There are no other long-range forces, but there is something else that is long range — the effects of spin. If you are near a spinning mass it will tend to spin you around with it, much as water swirls into a whirlpool. This process is known as frame dragging. In other words, you could determine whether or not a black hole was spinning by merely coming close to it. If you started to move around it, it is spinning; if not, it is a non-spinning black hole.

The solution to Einstein's field equations for spinning black holes was discovered in 1963 by Roy Kerr of the



University of Texas. We now refer to a rotating black hole as the Kerr black hole.

Scientists continued to look for other properties that are preserved when a star collapses to a black hole, but they have found none. Only these three — mass, charge, and spin — can be preserved. The mathematical proof of this is now known as the "No Hair Theorem," referring to the fact that a black hole has no other distinguishing characteristics.

Although nothing else is preserved, there is one other type of black hole. By looking at the various combinations of the above three properties we see that there is one we have not mentioned: the black hole that is spinning and also has charge. The solution for this case was found by Newman and several of his students in 1965 and is now referred to as the Kerr-Newman black hole.

In summary, then, there are four types of black holes: the Schwarzschild (which has only mass), the Reissner-Nordstrom (with mass and charge, but no spin), the Kerr (with mass and spin, but no charge), and the Kerr-Newman (which possesses all three properties). Let's look at what each of these types is like on the inside and how particles and light rays behave in this region. We'll also examine how things behave when they approach the black hole from the outside.

One way of probing the region around a black hole is through the use of light rays. We could, hypothetically, use a powerful flashlight to see how the severely curved space around the black hole affects the rays. There is, however, a second method of probing them. The curvature of spacetime affects particles of matter differently than it does light rays. We can, therefore, also use particles to probe black holes.

(Suppose, for the sake of simplicity, that we are investigating the black hole in a spaceship. Since the ship is, in essence, a particle, the orbit it takes is the same as that of a particle.)

Schwarzschild Black Holes

Let's begin with the simplest variety of black hole, the Schwarzschild black hole. As your spaceship passes through the event horizon it is pulled toward the singularity at the center of the black hole. If you looked back at the event horizon from just inside it, it would appear to be receding from you at the speed of light. In order to reach it, therefore, you would have to travel at this speed. But according to special relativity it is

impossible to travel this fast, therefore you can never get back to the event horizon.

Once inside this horizon all hope of escaping is lost. Space and time have interchanged their roles; where you once had control over space — you could go anywhere you wanted — you no longer do. Time is now the controlling factor, and there is nothing you can do to halt its passage. You are pulled inexorably toward the singularity, and once there you are crushed to infinite density.

Let's take a close look at this singularity. What exactly is it? According to Einstein's theory it is where all the mass of the collapsed star is. His equations seem to predict that the star's mass has no dimensions; it is a region of infinite density. But this conclusion comes from analyzing the solutions to Einstein's equations; in short it is a mathematical conclusion.

If we look at this conclusion in more detail we see that the theory has broken down. Before we could reach an infinite density we would enter the realm of quantum physics, an area in which Einstein's theory alone is not adequate. Einstein's theory deals only with objects on a macroscopic level; a quantum version of his theory is needed to address the nature of the singularity — a version we do not yet have. Without it we cannot predict what exactly happens at the center of a black hole. It is beyond our present physics. This is why, in fact, we refer to it as a singularity.

So much for the interior of the black hole. Let's return to the more predictable region away from the singularity. What would happen if we fell into a black hole? Suppose, for example, that there are two astronauts who are initially at some distance from the black hole. Assume that both of them have watches that have been synchronized. Further suppose that one of them, call him A, falls into the black hole.

What happens? At first A will accelerate toward it, just as he would here on Earth if he were falling from a great height. But then the second astronaut (B) will notice that A appears to be slowing down. The closer A gets to the event horizon, the slower he appears to travel. This is because A's time, as observed by B, is slowing down. If B continues to watch he will see that A's time almost stops, indeed it would stop if he reached the event horizon. But he never does; A appears to hover just above it.

Strangely, the sequence of events as described by A would be quite different. He does not notice that he is slowing down as he approaches the event horizon. To him it appears as if he falls right through it within a very short period of time. As best as he can tell, time runs normally for him. The curvature of spacetime by the gravitational field of the black hole causes these two different times, one experienced by astronaut A and one by B. They are called, respectively, "proper time" and "coordinate time" in the language of Einsteinian physics.

In addition to the strange behavior of time, tidal forces act on the astronauts. As astronaut A approaches the black hole he will be stretched by these forces. If he falls feet first, his feet experience a greater gravitational pull than his head. As he gets closer, his body will be stretched until it resembles a piece of string, with his height elongated without limit and his sides compressed to near nothingness. Obviously, no one could survive these circumstances.

Although our astronaut would be killed by these tidal forces far outside the event horizon of a stellar-sized black

hole, it would be possible for him to pass through the event horizon of a much more massive black hole without being pulled apart.

It might appear from what we've seen so far that black holes are ominous monsters waiting to suck us in and crush us. But this isn't actually so. If our Sun, for example, suddenly became a black hole, the Earth would remain in the same orbit it has always been in and would *not* be pulled into the black hole. This is because the gravitational field at the position of the Earth would be the same after the Sun became a black hole as it was before. The basic difference is that you can get much closer to the source of the gravitational field now. The black hole that is creating the field is only a few kilometers across, whereas the Sun has a diameter of 1,392,000 kilometers. And as you get closer the gravitational field grows increasingly stronger.

One way to observe this increased strength is by the strange behavior that an object, say a planet or asteroid, would display if it were in an elliptical orbit close to the black hole. The major axis of its ellipse would precess (move around) very rapidly. We know this effect occurs for all objects in elliptical orbits (and can actually be observed in Mercury's orbit), but when the gravitational field is weak the effect is small.

Mathematically, the solutions to Einstein's equations lead us to another interesting conclusion. It seems there are only two types of possible particle orbits around black holes. They are referred to as orbits of the first and second kind. The first kind are closed stable orbits, such as the one discussed above. The second kind are orbits in which the particle spirals into the singularity. Which of these two types of orbits occur for a particle approaching a black hole depends on the particle's mass, velocity, and direction of travel relative to the black hole.

Now let's use light rays to probe the vicinity of a Schwarzschild black hole. Assume that a massive star, one large enough to end as a black hole, has begun its final collapse and you are on its surface with a powerful flashlight in your hands. (In practice the star would collapse in a fraction of a second, but we'll slow it down so we can see what is going on.) As the star begins its collapse you shine the light around to check out the effects of the increasing curvature of spacetime on the rays. Initially you might notice that the rays of light are slightly deflected by the gravitational field of the star, as they are in the vicinity of the Sun, though the rays do not have a problem escaping. Eventually you reach a point where shining your light parallel to the star's surface will cause the rays to be caught in a circular orbit around the star. This region of a black hole is called the photon sphere.

The next thing you notice is that any rays pointing toward the star's limb are pulled into the star. A short time later rays at several degrees to the limb are pulled in. You notice, in fact, that there is a cone-shaped region perpendicular to the surface of the star in which rays are able to escape, but rays outside of the cone are captured. This area is referred to as the exit cone. As the star continues to collapse, the cone gets narrower and narrower until it finally closes as you pass through the event horizon.

Reissner-Nordstrom Black Holes

The charged, or Reissner-Nordstrom, black hole is quite different from the Schwarzschild black hole. Since the details depend on the net charge, we'll start with a hypothetical black hole that is electrically neutral and add charge a little at a time. In the initial uncharged state there

Types Of Black Holes



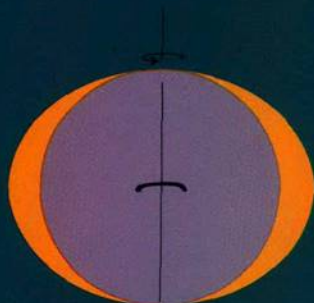
Schwarzschild

Simplest type. Lacks both charge and spin. Has only one event horizon and a single photon sphere. Energy cannot be extracted from it. Contains a point singularity where matter is crushed to an infinite density.



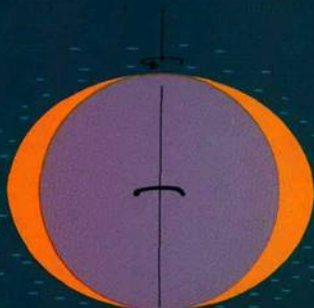
Reissner-Nordstrom

Has charge but no spin. Can have two event horizons [for simplicity only one is shown in these diagrams], but only a single photon sphere. Contains a point singularity. Unlikely to occur in nature due to charge neutralization.



Kerr

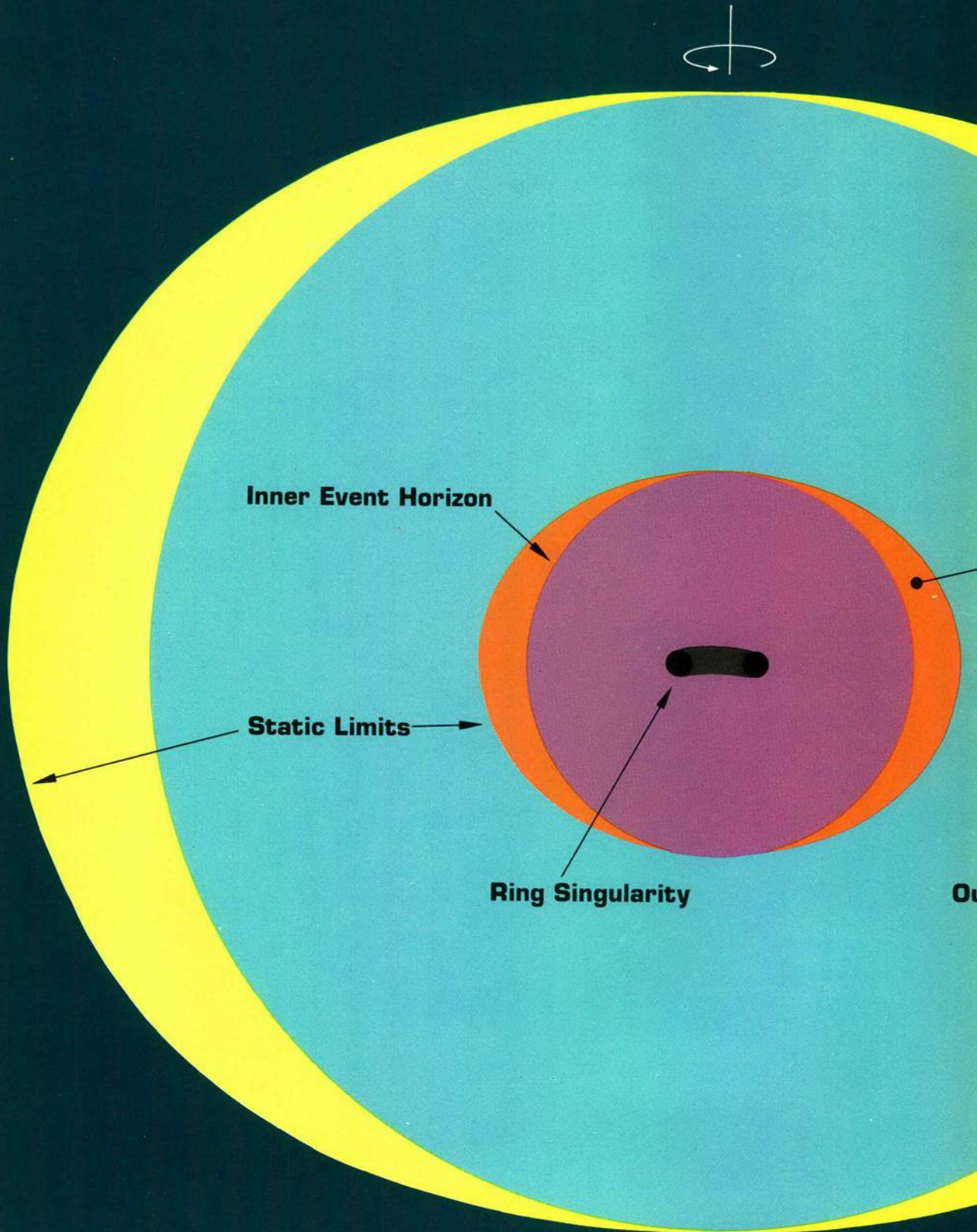
Has spin but no charge. Outer ellipsoid is static limit, shaded region between event horizon and static limit is ergosphere, from which energy can be extracted. Can have two event horizons and two static limits. Has two photon spheres. Contains a ring singularity.



Kerr-Newman

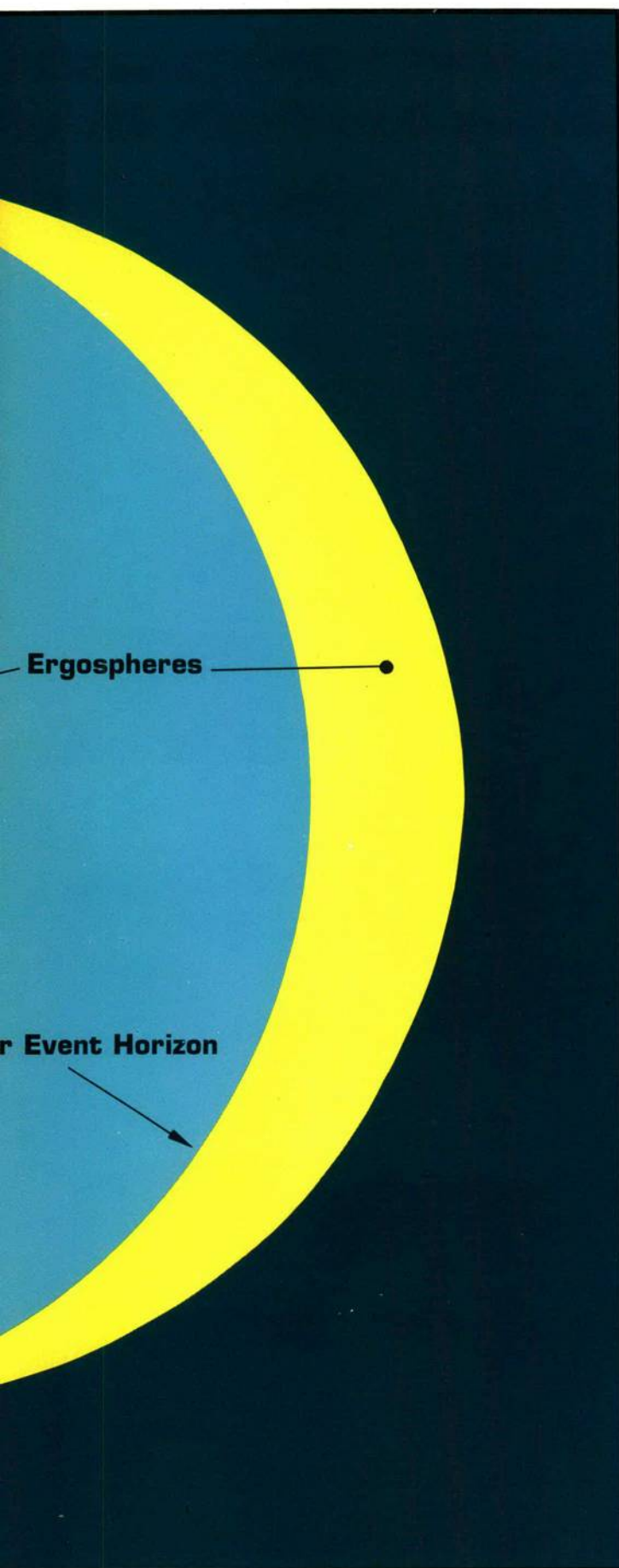
Has both charge and spin. Same as the Kerr black hole except it has charge. Structure is similar to the Kerr black hole. Energy can be extracted from it. Contains a ring singularity.

The Detailed Structure Of A



When a spinning body collapses to form a black hole, the spin strongly influences the resulting structure. In most cases the event horizon splits in two and an associated static limit forms just outside of each. Once inside a static limit it is impossible to remain stationary, although it is still possible to escape. Between the event horizon and the static limit is the ergosphere. At the heart of the black hole lies a singularity, but for a Kerr black hole it is in the shape of a ring.

Kerr Black Hole



is only one event horizon, but the moment we add charge something strange happens. The original horizon begins to shrink and a second horizon appears closer to the singularity. If you continue adding more charge, the outer event horizon will continue to shrink while the inner one moves outward until eventually the two merge. Although the inner event horizon will always be hidden from the outside universe (because it is inside of the outer event horizon), the two horizons each have the same properties as the event horizon in a Schwarzschild black hole.

What happens if you add even more charge? As you might expect, the event horizon shrinks. And if you continue adding more charge the horizon will continue to shrink until it finally is a tiny surface just above the singularity. If you add any more charge at this stage the event horizon will suddenly and completely disappear. You are left with only the singularity, but it is no longer clothed in an event horizon. It is a naked singularity.

A naked singularity in nature would be a strange thing to behold. You would see nothing ahead of you — for a singularity has no dimensions — then suddenly you would be pulled into it and crushed. Astronomers are still uncertain, though, whether the extreme conditions necessary for their formation can ever exist, or if naked singularities are prohibited by the laws of physics in a form of “cosmic censorship.”

Kerr Black Holes

Kerr black holes are the most interesting type of black hole because they exhibit the widest range of characteristics. Beginning with a non-spinning black hole and gradually adding spin, we again see that the event horizon shrinks and an inner one appears close to the singularity. As we add more spin the outer one moves inward and the inner one moves outward.

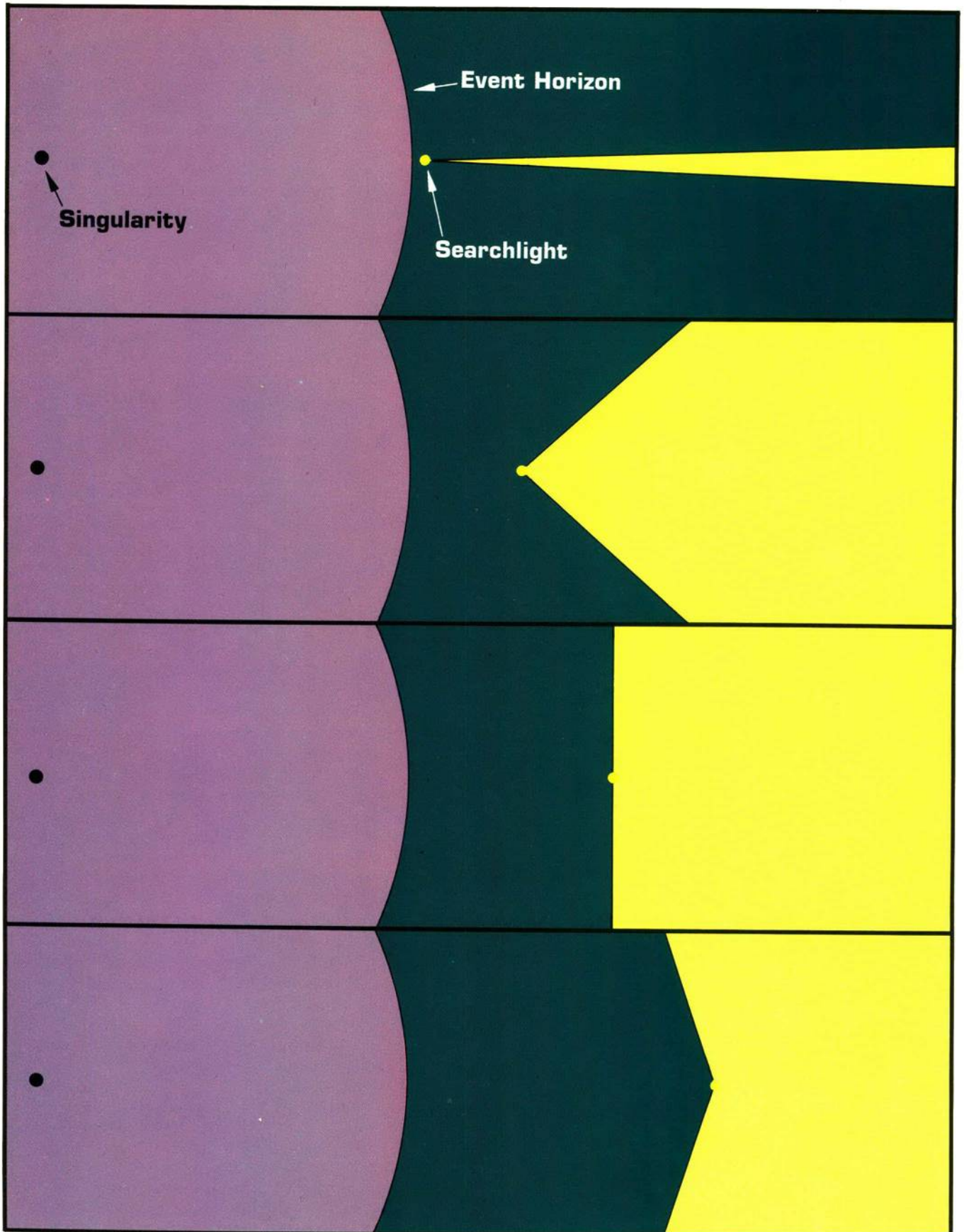
But there is a difference between this case and the charged black hole, and that difference is related to the static limit. The static limit is the position surrounding the black hole where a particle can no longer remain at rest. For Schwarzschild black holes we saw that this was at the event horizon; it took a velocity equal to that of light to remain at rest there.

To see where the static limit is in the case of a Kerr black hole let's assume we are approaching one in our spaceship. Because of frame dragging we will be pulled around the black hole in the direction of its spin. Far from the black hole, however, we can easily arrest this motion by firing the retrorockets. As we get closer and closer to the black hole it takes more and more of a blast to remain motionless until finally we are dragged around the black hole regardless of our efforts. At this point we are inside the static limit, which is a surface around the black hole lying just outside the event horizon. The static limit touches the event horizon at both poles and has maximum separation from it at the equator of the black hole.

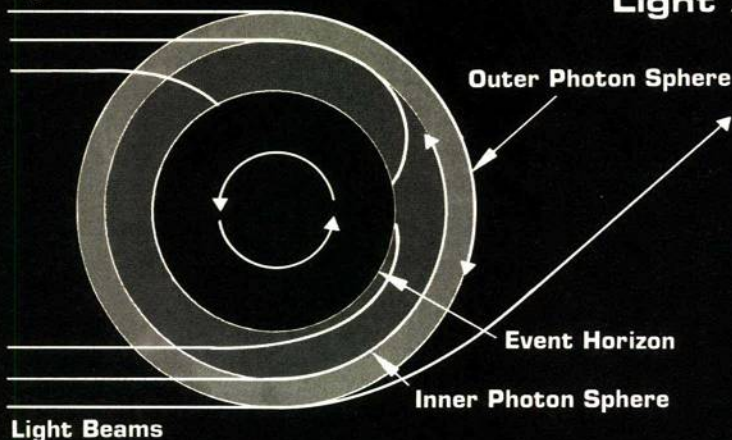
Although you cannot remain stationary once inside the static limit, you are not yet trapped inside the event horizon. You can still escape from the black hole if your rockets can get you going fast enough.

Between the static limit and the event horizon is the strange region called the ergosphere. In 1969 Roger Penrose of Oxford University showed that we could use the ergosphere to extract energy from a black hole. If, for example, we launched an object into the ergosphere that would break in two once inside it, and if one piece fell into the singularity and the other emerged, the piece that emerged would come out with considerably more energy

Probing A Black Hole With Light



An observer probes the space around a Schwarzschild black hole by using a powerful searchlight. When he is close to the event horizon (top), only light aimed into the narrow cone-shaped region (yellow) escapes. Any other light is drawn to the event horizon and finally into the singularity. As the observer moves away, the light cone becomes wider. The third diagram shows the location of the photon sphere, the region where a beam of light parallel to the event horizon is trapped in a circular orbit.



When a beam of light encounters a spinning black hole, its path is determined by the direction of its approach. Coming in opposite to the black hole's spin (top), the beam gets caught in a circular orbit at the outer event horizon. Any beam aimed closer to the black hole will be drawn in. If a beam approaches in the same direction as the black hole's spin (bottom), it gets caught in a circular orbit closer to the event horizon at the inner photon sphere. Any beam aimed further away will merely be deflected by the black hole, and any aimed closer will be trapped.

than the original object had. Instead of sucking in everything surrounding it, a black hole can actually be a source of energy. As more and more energy is extracted from the black hole, however, it spins slower and slower until it finally becomes a Schwarzschild black hole.

As we added spin to the Kerr black hole, we noticed that two event horizons formed. But since all event horizons in spinning black holes are surrounded by static limits, there are also two static limits and two ergospheres. As we continue to add spin they approach one another until finally they merge. With the addition of even more spin both the event horizon and static limit move toward the singularity and eventually, as in the Reissner-Nordstrom charged black hole, the event horizon disappears, leaving only a naked singularity.

When physicists explore the equations describing the singularity itself, they find another difference between the rotating and charged black hole. The singularity is no longer a point, it is a ring. Kerr black holes have ring singularities.

We previously mentioned that we don't expect to find Reissner-Nordstrom black holes in nature because any charges tend to get neutralized. On the other hand, Kerr black holes are the most likely kind to form. The reason for this is that all stars spin. As a spinning star collapses it spins faster and faster, conserving a quantity known as angular momentum. This same principle comes into play when a spinning figure skater pulls her outstretched arms to her side and spins much faster. When a massive star collapses it ends up spinning almost fast enough to lose its event horizon by the time it becomes a black hole. In short, it is almost spinning fast enough to end as a naked singularity.

Turning now to the outside of the Kerr black hole we find again that light rays and particles behave quite differently from each other. Consider light rays first. Earlier we introduced the photon sphere, the surface around the black hole where light rays, assuming they came in parallel to the surface, get caught in a circular orbit. If you were outside the black hole probing the region around it with a flashlight this is where the beam would move in a circle around the black hole. The photon sphere is normally one and a half times further from the singularity than the event horizon.

What happens to the photon sphere when we add spin? Not surprisingly, it breaks into two photon spheres. The outer one is slightly further out than the Schwarzschild

photon sphere, and the inner one is slightly closer to the singularity. As more and more spin is added they separate more and more.

But how do these photon spheres differ? To answer this we must first notice that the spinning black hole has a distinctly different property from the non-spinning one. It has a spin axis that points in a particular direction in space.

Let's assume we are examining the space around the black hole with a flashlight. For simplicity we'll assume we are in the plane of the equator. As we bring the beam closer and closer to the black hole we see it is bent more and more. And eventually, at the outer photon sphere, it is caught in a circular orbit. If we looked at the black hole we would see that, in this case, it is spinning in the opposite direction from which the light is moving. In other words, if the black hole is spinning clockwise, the beam is going around the black hole in the outer photon sphere in a counterclockwise direction.

Now switch the beam over so it will be orbiting in the same direction as the hole is spinning. This time you get it much closer to the black hole before it is captured by a photon sphere — the inner photon sphere.

Between these photon spheres is a whole range of possible circular orbits, but only for rays that come in at an angle to the equatorial plane.

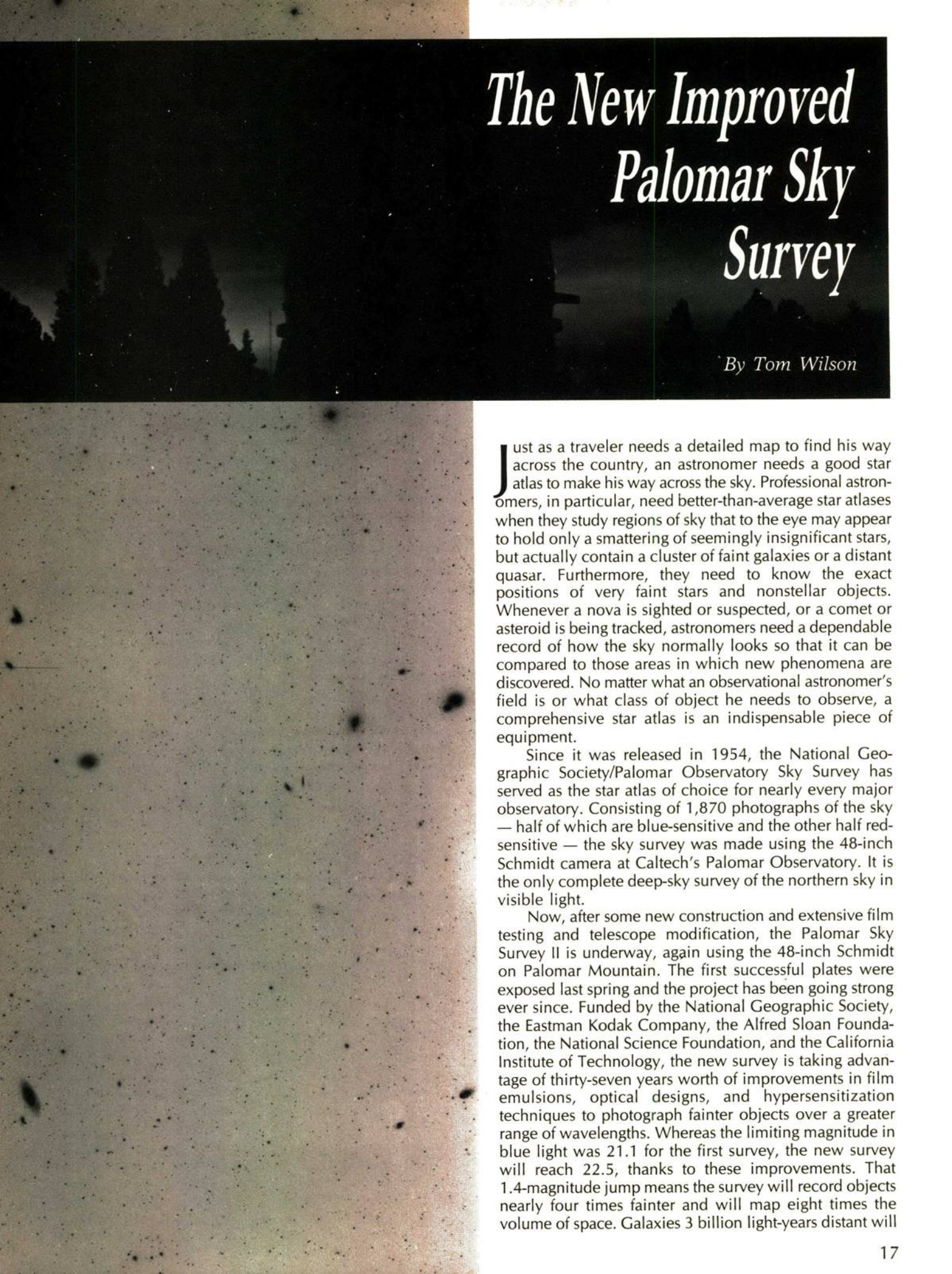
We have seen how particles and light rays behave around black holes. It is important to remember, though, that our predictions are theoretical ones obtained from general relativity. This, of course, leads to the question: Have we checked out any of these predictions observationally? Embarrassingly, we have not.

There are several excellent black hole candidates: Cygnus X-1 is the most convincing case of a stellar-sized black hole, and M-87 is expected to harbor a supermassive black hole at its center. Most astronomers believe that active galaxies and quasars are powered by these exotic objects. The problem in confirming their existence is that they are so small and far away that it is extremely difficult to determine how light rays and particles are affected as they pass near them. With new discoveries, however, someday this may be within our grasp.

Barry Parker is the author of Einstein's Dream, published in 1986 by Plenum Press. He is an astrophysicist at Idaho State University who last wrote for ASTRONOMY on "The Mysterious Cosmic X-Ray Background" in the February 1986 issue.



The Virgo cluster of galaxies. Photo © 1960 National Geographic/Palomar Sky Survey. Reproduced by permission of the California Institute of Technology.



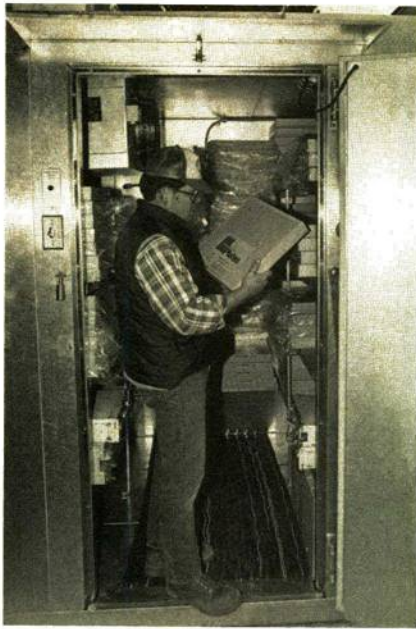
The New Improved Palomar Sky Survey

By Tom Wilson

Just as a traveler needs a detailed map to find his way across the country, an astronomer needs a good star atlas to make his way across the sky. Professional astronomers, in particular, need better-than-average star atlases when they study regions of sky that to the eye may appear to hold only a smattering of seemingly insignificant stars, but actually contain a cluster of faint galaxies or a distant quasar. Furthermore, they need to know the exact positions of very faint stars and nonstellar objects. Whenever a nova is sighted or suspected, or a comet or asteroid is being tracked, astronomers need a dependable record of how the sky normally looks so that it can be compared to those areas in which new phenomena are discovered. No matter what an observational astronomer's field is or what class of object he needs to observe, a comprehensive star atlas is an indispensable piece of equipment.

Since it was released in 1954, the National Geographic Society/Palomar Observatory Sky Survey has served as the star atlas of choice for nearly every major observatory. Consisting of 1,870 photographs of the sky — half of which are blue-sensitive and the other half red-sensitive — the sky survey was made using the 48-inch Schmidt camera at Caltech's Palomar Observatory. It is the only complete deep-sky survey of the northern sky in visible light.

Now, after some new construction and extensive film testing and telescope modification, the Palomar Sky Survey II is underway, again using the 48-inch Schmidt on Palomar Mountain. The first successful plates were exposed last spring and the project has been going strong ever since. Funded by the National Geographic Society, the Eastman Kodak Company, the Alfred Sloan Foundation, the National Science Foundation, and the California Institute of Technology, the new survey is taking advantage of thirty-seven years worth of improvements in film emulsions, optical designs, and hypersensitization techniques to photograph fainter objects over a greater range of wavelengths. Whereas the limiting magnitude in blue light was 21.1 for the first survey, the new survey will reach 22.5, thanks to these improvements. That 1.4-magnitude jump means the survey will record objects nearly four times fainter and will map eight times the volume of space. Galaxies 3 billion light-years distant will



Top left: Hundreds of glass plates are visible inside the film vault as Merle Sweet makes a selection. The temperature in the vault is kept at a constant 21 degrees Celsius. Plates are obtained in large lots to minimize the testing necessary to determine relative sensitivity among lots. From here, the plates are transferred into the hydrogen building for hypering. **Top right:** Adjustments to the mirror supports, being done here by Mike Carr, are checked by a knife-edge test performed at the corrector lens end of the telescope tube. All photos by Tom Wilson.

appear on the plates, making the current effort truly a deep-sky survey.

Better Film for the New Survey

Photographic films have come a long way since the original survey. Back then, exposures were made using 103a-O blue and 103a-E red Kodak glass plates measuring 14 inches square. The big advantage of these emulsions was their speed; exposures were only 10 to 15 minutes for the blue and 40 to 60 minutes for the red. However, like any high speed emulsion they had a coarse grain that limited detail in faint objects.

The new plates are the IIIa spectroscopic type made by the Eastman Kodak Company. The blue-sensitive emulsion is designated IIIa-J and the red-sensitive is IIIa-F. The IIIa boasts a finer grain structure than the 103 series, so its resolving power is greater. The drawback, of course, is that the IIIa emulsion is slow, thus requiring longer exposure times. Survey astronomers are planning on exposing each plate for 60 to 90 minutes, even after hypersensitizing.

Infrared photographs will be made using plates prepared with Kodak's infrared-sensitive IV-N emulsion. Because infrared light penetrates clouds of interstellar dust, photographs sensitive to this region of the spectrum will help astronomers probe more deeply into interstellar dust clouds and identify both red supergiants and small, cool, red stars, as well as those stars dimmed by interstellar dust. Additionally, the IV-N plates will give stellar astronomers a better look into dust-shrouded young stars.

Hypering Innovations

Film hypering in general is still something of a primitive art in that new methods for increasing film speed and reducing reciprocity failure are constantly being developed. Basically, gas hypering purges oxygen and

moisture — two elements that act as desensitizers and reduce film speed — from the film emulsion.

The glass plates used for the original survey were hypered by baking them in a vacuum for long periods of up to thirteen hours. The latest hypersensitizing method for the IIIa emulsions is soaking each plate in a container of nitrogen and subjecting it to ten-minute bursts of hydrogen each day. This is done for a week, after which the plate is soaked in pure hydrogen for four hours prior to use.

However, the longer the alternating soak, the shorter the pure hydrogen soak at the end of the cycle. In fact, if the alternating soak runs for four weeks, no pure hydrogen soak is required before using the plate. As the Sky Survey progresses and more plates are used, additional plates can be started on the long hypering process. For now the shorter alternating soak makes plate scheduling more flexible and minimizes plate wastage due to unpredictable weather and periodic equipment failure.

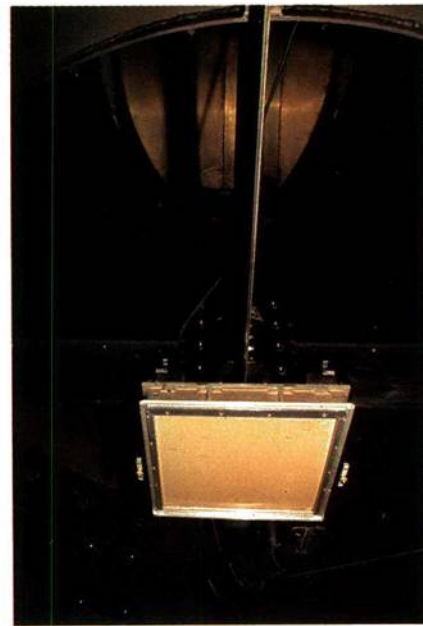
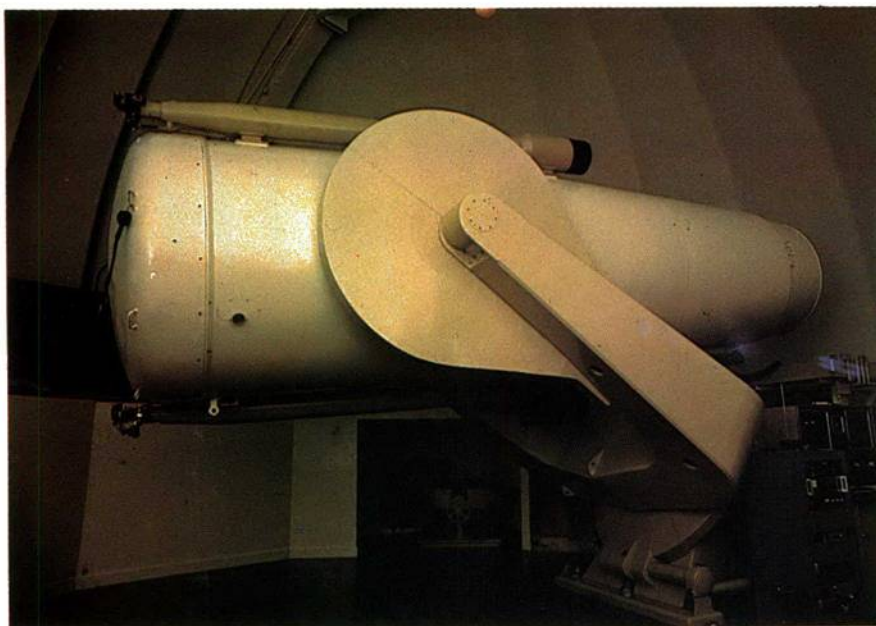
As anyone who has set a match to a test tube of hydrogen knows, working with this flammable gas is extremely hazardous. To minimize the risk, a special hypersensitizing building was erected on Palomar Mountain complete with explosion-proof electrical outlets and switches, enclosed light fixtures, static-proof floor tiles, and a peaked, vented roof to exhale any accumulated gas. The precautions are extensive, even though the chance of a mishap seems remote. Nevertheless, the Palomar staff has dubbed the building "the Hindenburg Cottage."

Infrared plates are hypered in a completely different way. Plates are given a five-minute silver nitrate solution bath, followed by an alcohol wash/stop and a fifteen-minute forced air drying. Since the infrared plates must be exposed immediately after hypering, they are hypered one at a time.

Telescope and Optical Improvements

Although the new survey is being done with the same 48-inch Schmidt telescope used in the first survey, better images will be produced on the plates due to substantial modifications made to the telescope.

A Schmidt camera resembles a normal reflecting telescope at first glance, but it differs in several important aspects. Instead of the reflector's parabolic mirror, which



can focus on only a small part of the sky, a Schmidt telescope uses a spherical reflecting surface that focuses any light that passes through its center of curvature. Unfortunately, spherical mirrors suffer from spherical aberration, in which light rays do not converge at a single point. Therefore, a thin lens is fitted to the front of the Schmidt camera tube, at the mirror's center of curvature, to refract the incoming light so all the rays focus at the same point.

The original corrector lens on the Palomar Schmidt was a single piece of glass that could perfectly correct light at only a single wavelength (4,861 Angstroms). All other wavelengths were refracted imperfectly and the "correction" fell off on either side of the optimum wavelength. However, a new two-element achromatic corrector has been installed, which will allow a much broader range of wavelengths to be photographed. A two-element corrector corrects light at two optimum wavelengths, providing a plateau from 4,000 to 9,000 Angstroms. This gives a usable range of 3,800 to 10,000 Angstroms, yielding blue images equal to those of the original corrector, better red images, and allowing good near-infrared photography.

The camera's optics have also been finely tuned for optimum performance. When the new correcting lens was installed, knife-edge tests (Foucault tests, which reveal the optical contour of a mirror) showed that the mirror was slightly warped. Investigation revealed that three pairs of the weighted, gravity-compensating mirror supports had been spring-loaded to keep the mirror against three Invar rods (special iron alloy rods with high strength and a low coefficient of expansion) that run between the mirror and the plate holder. The supports were pressing the mirror at points slightly to each side of the Invar rods, distorting the mirror around the end of the rods. After a redesign, the supports apply force at points directly opposite the Invar rods, and the mirror is again spherical. In the mirror supports themselves, 108 bearings, which were over forty years old, were replaced with new bearings to reduce friction.

Another improvement currently being developed is an automatic guider. Because it is impossible to put an eyepiece on a Schmidt camera, all guiding during exposures must be done with guidescopes. The Palomar

Top left: The 48-inch Schmidt, seen here parked in its horizontal position, appears as it did for the first sky survey, but a new corrector lens has increased its performance. **Top right:** Looking up and forward inside the telescope, a plate is visible on the spider. The plates are raised or lowered onto the spider by an electric elevator and are automatically removed or installed into a light-tight transport box at the bottom of the elevator. The gold oval area in the background is the telescope's shutter, which seals the telescope until opened for the exposure.

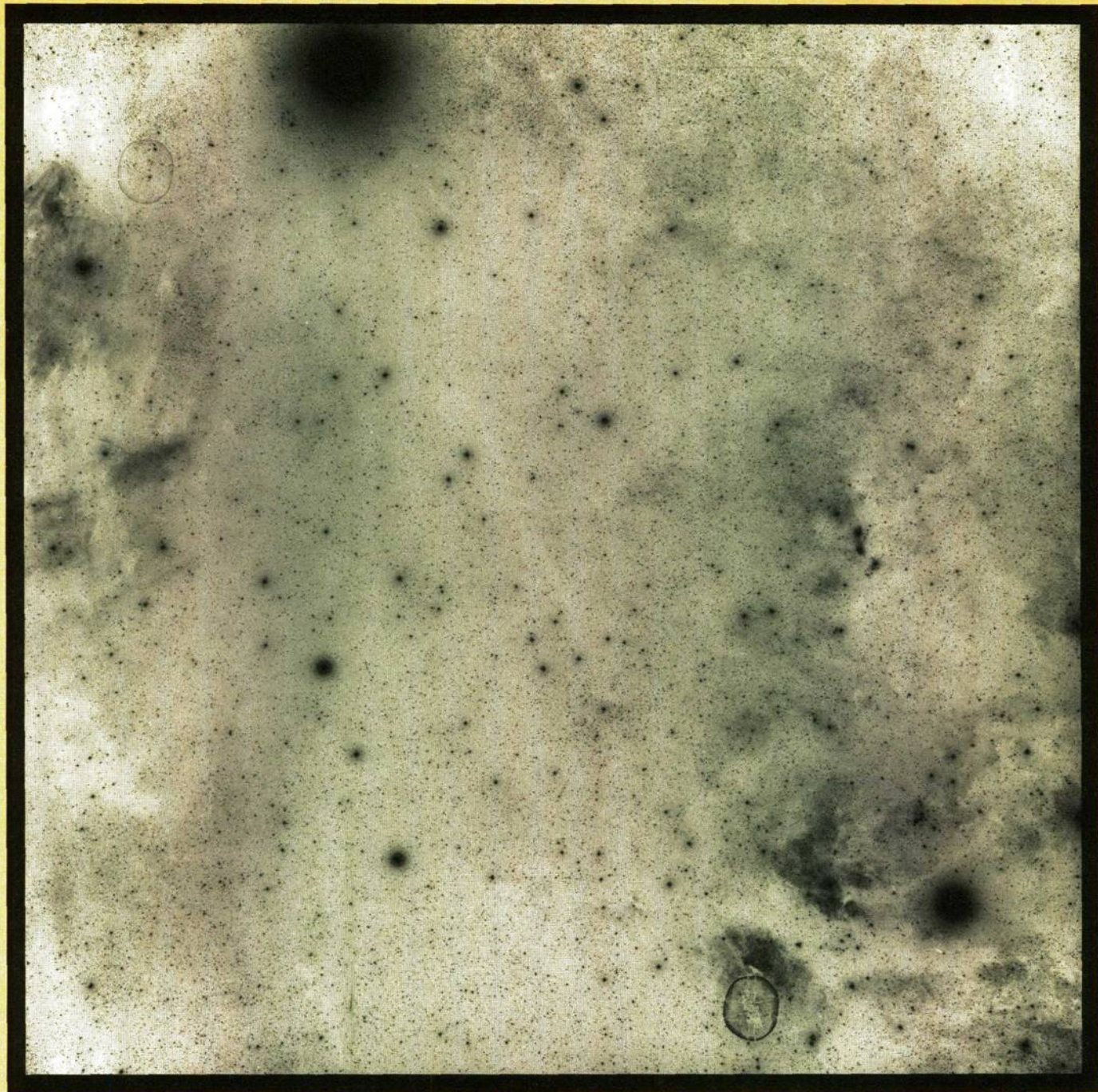
Schmidt uses two 10-inch refractors for this job. Guide stars can be as faint as 9th magnitude, and they need not be centered in the field.

The auto guider will lock onto the guidescope image by means of a computer, freeing the astronomer of guiding chores. But until the auto guider is perfected, the telescope will still be guided the time-honored way: eye to the guidescope with control paddle in hand.

Telescope improvements cap off an impressive list of rebuilt facilities inside the dome of the 48-inch. Almost the entire lower floor of the observatory building was gutted and two new darkrooms, a plate inspection room, and chemical mixing room were built, as well as a dinette and two offices. The plate-loading room was also expanded. An air conditioning system was installed to keep the air within one degree of the pre-set temperature, which is about 21 degrees Celsius (70 degrees Fahrenheit), and at exactly 50 percent humidity while filtering out impurities down to one micron. All this, along with constructing the hydrogen hypering building and film vault, was accomplished in nine months by Bob Thicksten, superintendent of the observatory, and his crew, who normally work as maintenance men, not builders.

Anticipated Scientific Benefits

Of course the only reason for doing Sky Survey II is the scientific benefits to be achieved from it. When combined with a southern sky survey now in progress at the European Southern Observatory at La Silla, Chile (which is using the same IIIa emulsions), and the survey using blue-sensitive plates completed in 1983 by the United Kingdom Science and Engineering Research Council Observatory in Australia, the new survey will complete a total, complementary examination of the sky as seen from Earth. Plates from both hemispheres will offer



astronomers the largest possible area for comparison studies.

A major benefit to be gained from the new survey will be to see how the night sky has changed since the 1950s. We often think of the stars as being constant, yet there is change, even if only visible at the photographic level. The fine grain and high contrast of the new films used in the U.K. survey revealed faint envelopes around galaxies and emission nebulae in our own galaxy. These features were only barely visible or invisible on the first Palomar survey, and Caltech astronomers are anxious to record them on Sky Survey II.

When Sky Survey II is complete it will be possible to compare positions on the first and second surveys of literally thousands of stars. Determining proper motions — the apparent motions of stars on the celestial sphere — on a wholesale scale will then be possible. Of particular interest are those stars that figure prominently in certain

fundamental questions such as galactic rotation and possibly the missing mass problem.

Another area of interest sure to carry over from the first survey is the study of galaxy clusters. George Abell, who published a catalogue of rich clusters of galaxies in 1958, identified hundreds of galaxy clusters on Survey I plates. The 48-inch Schmidt camera has the wide field of view and the light-gathering ability to photograph widely dispersed, distant phenomena like superclusters of galaxies. With the Sky Survey II looking deeper yet, that many more galaxy clusters, superclusters, and, perhaps, voids (regions in extragalactic space that seem to be without matter) will be identified, helping with missing mass and cosmology studies.

Broken Plates and Satellite Tracks

It is difficult to determine just how many plates will be needed for the entire survey. In the original survey 3,240 plates were exposed to obtain 1,870 acceptable



examples. This means there were 935 pairs of blue and red plates in the finished survey that went all the way to -33° declination with plates centered 6° apart from each other. But because the southern sky survey will cover the southern celestial hemisphere, the northern sky survey need only cover the northern celestial hemisphere. This means that there will be fewer fields to photograph — a total of 894. Offsetting this reduction of the workload, however, is the additional set of infrared plates that Sky Survey II has to make. Moreover, there is some uncertainty about the number of plates that will be spoiled by clouds, excessive sky brightness, bad seeing, emulsion defects, airplane and meteor trails, and focusing errors.

A relatively new concern is satellite tracks. Incredible as it seems, one out of three plates are expected to be streaked by one or more satellites traversing the field. Such plates will be marked as cosmetically defective and placed on the re-shoot list. They will be retained for scientific

The dramatic difference between blue (opposite page) and red (above) exposures is shown by this pair of prints. Both are of the same region of Cygnus, but the strong emission and absorption regions record differently. Small halos caused by internal telescope reflections appear at the upper left and lower right corners. The bright star at the upper left is Deneb. Photo © 1960 National Geographic Society/Palomar Sky Survey. Reproduced by permission of the California Institute of Technology.

study but won't be copied and distributed in the finished survey.

Taking all of these potential hazards into account, survey astronomers estimate that 50 percent of the plates will require re-shooting.

Another problem is that glass plates break. In order to make them pliable enough to be bent onto the telescope's curved plate holder, the plates are only one millimeter thick. The plates are held in a frame that is curved to the same center of curvature as the spherical

mirror, otherwise only the center of the image would be brought to focus. The frame has rotating handles and fits into the telescope along with the plate. Breakage at the telescope is practically nonexistent, as the plates are held in the frame from the time they are loaded in the darkroom through developing. Some breakages are inevitable, but chances are they will occur during subsequent handling.

And of course light pollution is a problem to contend with in the 1980s. The sky is now twice as bright around Palomar as it was during the first survey. This light pollution extends to every part of the sky above the observatory, but some of the heaviest concentrations are to the south. Staying north of the celestial equator, however, will spare the survey plates from being fogged by lights from San Diego.

A sad commentary on Palomar's light pollution is illustrated by accounts of the first survey. In those days it was considered necessary to expose plates during sunspot minima when the amount of airglow (a suffusive glow in the upper atmosphere caused by solar radiation) was more subdued. As the sunspot cycle grew toward a maximum following 1956, the sky brightness practically doubled above Palomar from the airglow. Now sunspot activity is considered a second-order problem compared with the wayward emissions and misuse of Mr. Edison's invention. More important now are those nights when low clouds shroud San Diego's glare, yet leave the 5,600-foot observatory clear.

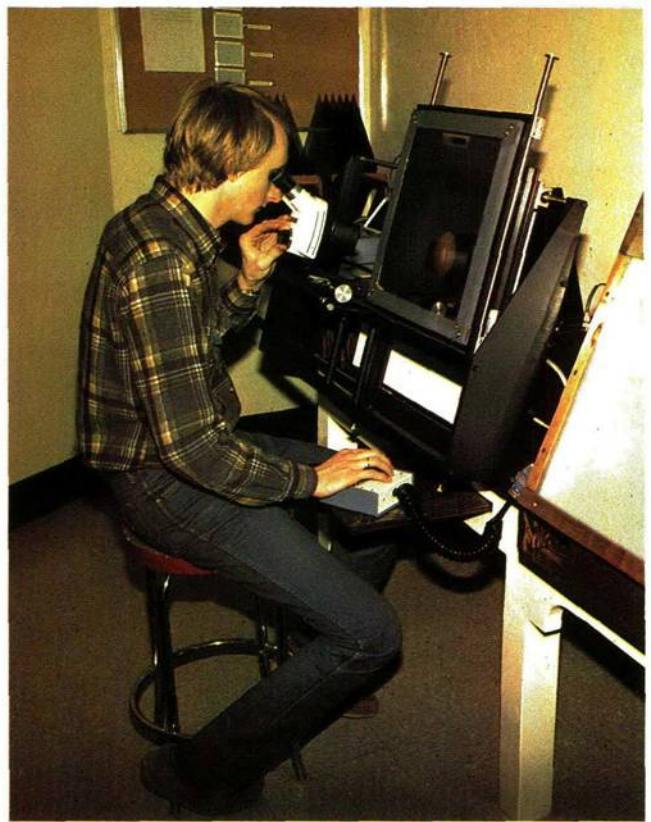
How Long Will It Take?

The bulk of the original survey was completed in about five years, from 1949 to 1954. But repeated efforts to photograph those fields that seemed to defy success, plus scheduling and weather constraints, meant that some survey plates were taken ten years after the beginning of the project. If five years seems like a long time for catch-up work, consider that both blue and red plates had to be taken back-to-back on the same night to qualify as a successful survey pair. Therefore, if one plate was ruined before a replacement could be exposed that night, both plates had to be re-shot another night.

The new survey will probably take the same amount of time to complete as the original, even though there is a third plate to shoot for each field. The time necessary to shoot the third infrared plate will be compensated for by not having to shoot all the plates on the same night. The "same night" requirement was dropped for the new survey. The planners decided that the benefits of such a tight exposure schedule are outweighed by the time limitations of the longer exposures and three films.

As with the first sky survey, Sky Survey II will be available to interested parties wanting a complete set or certain selected prints. However, the quality of the materials of the new survey has been upgraded.

In the original survey, all photos were assembled into a sky atlas, which was made available on an at-cost basis. The atlas came in either glass plate or paper print form. Both the glass plates and paper prints were negatives, because they reproduce faint images better than positives. Two sets of glass plate positive copies from the original sky survey were made at Caltech's Pasadena photography lab for reproducing other copies. One set was sent to Palomar Observatory for safekeeping, the other remained on campus for copy use. The original plates were also kept at the Caltech campus where they are available to the staff. About thirty glass plate sets and several hundred paper print sets were sold.



For astronomers, much of the excitement of the Sky Survey is in examining the plates right after they come out of the darkroom, as photographic scientist Alain Maury is doing here. The plate inspection room is adjacent to the darkroom in the Schmidt's dome and is outfitted with light tables and a stereoscope inspection device. Incredible detail can be seen in the negative plates when viewed through the stereoscope, which is graduated and equipped with electric x-y motion.

Survey II distribution will follow the same sequence, except that film transparencies are being substituted for negative paper prints. The transparencies are a great improvement because they reproduce the same dynamic range as the original glass plates yet are cheaper to copy and easier to handle.

However, glass plate copies will still be available. Glass plates have the advantage of a higher density range than paper prints, plus they keep their shape. Thus, an astrometric astronomer measuring precise star positions will want glass plates. The penalty is the considerable expense of the glass plus the obvious problems of weight and breakage. Not all astronomers require the exactness of a glass plate, and many are happy with the cheaper, lighter, easier-to-handle transparencies.

No matter what form it is in, the Palomar Sky Survey II will surely become as important as its predecessor, if not more so. Its combination of fainter images, finer resolution, an infrared component, and compatibility with the southern sky surveys will have a significant effect on observational astronomy. In addition, considering that the first survey turned up a number of new galactic clusters, comets, and asteroids, it is also possible that similar surprises await us as the second survey begins.

Tom Wilson is a freelance writer living in Fallbrook, California, specializing in automotive technical writing and science writing. His last article, "Getting Away to It All," appeared in May 1981.

The sky's no limit.

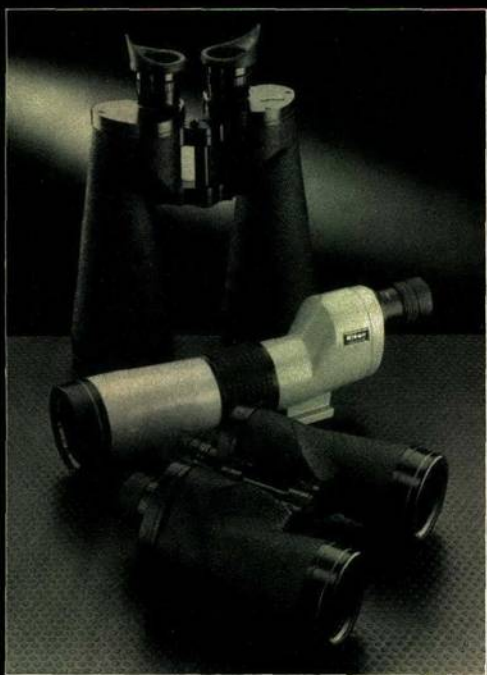
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ASTRONOMY Forum

Bayer's Lost Star

If you compare the stars in the constellation Andromeda in Johannes Bayer's *Uranometria* of 1603 (that famous star atlas where Greek letters were first used to name stars) with any modern star atlas, you will make a fascinating discovery. All the stars on the *Uranometria* will match fairly accurately with those on the modern atlas — all, that is, but one.

On modern star atlases, the star 50 Upsilon (υ) Andromedae is shown about 1° northwest of Tau (τ) Andromedae, but on Bayer's atlas a star labeled Upsilon appears about 2° northeast of Tau. The reason for this discrepancy is quite simple: the star that is today called Upsilon Andromedae is not the same one that Bayer originally called Upsilon. He marked an entirely different star, but because of a fascinating series of blunders by a

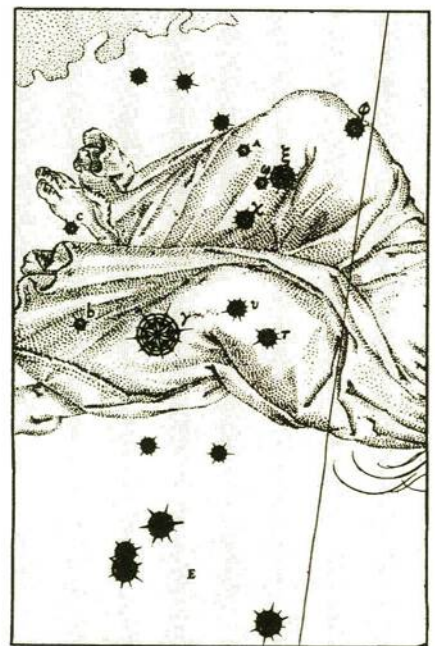
prominent astronomer, the star Bayer charted and named lost its Bayer designation and consequently its status and prominence as a named star.

The star that Bayer marked Upsilon is named HR 483 in the modern *Yale Bright Star Catalogue*, but it was, at one time, a recognized member of the stellar community. Claudius Ptolemy listed it in his second-century catalogue, the *Almagest*, as the eighteenth star in Andromeda. This gave the star an enduring place in subsequent star catalogues. Ptolemy's work was copied and recopied, and served as the basis for virtually every star catalogue and atlas that appeared over the next 1,500 years, including the Alfonsine Tables of 1252.

In 1540, at the dawn of the modern era, Alessandro Piccolomini included this star in his *De Le Stelle Fisse Libro*

Uno, the first star atlas that used letters of the alphabet to identify stars. Half a century later, Tycho Brahe, the father of European observational astronomy, also noted the star. He listed it as 19 Andromedae in his catalogue of 777 stars and again in his later but less accurate catalogue of 1,000 stars. A few years later, Bayer, who relied heavily on Tycho's work, noted this star in his own catalogue and listed it as 20 Andromedae in his atlas and catalogue of 1690, *Prodromus Astronomiae*.

Even Eastern astronomers took note of HR 483. It was included in the works of the tenth-century Persian astronomer Al-Sufi and possibly in the fifteenth-century catalogue of the Mongol Ulug Beg, depending on which manuscript source is consulted. In sum, this star was observed and catalogued by every one of the great classical astronomers, from the ancient world until the eighteenth century.



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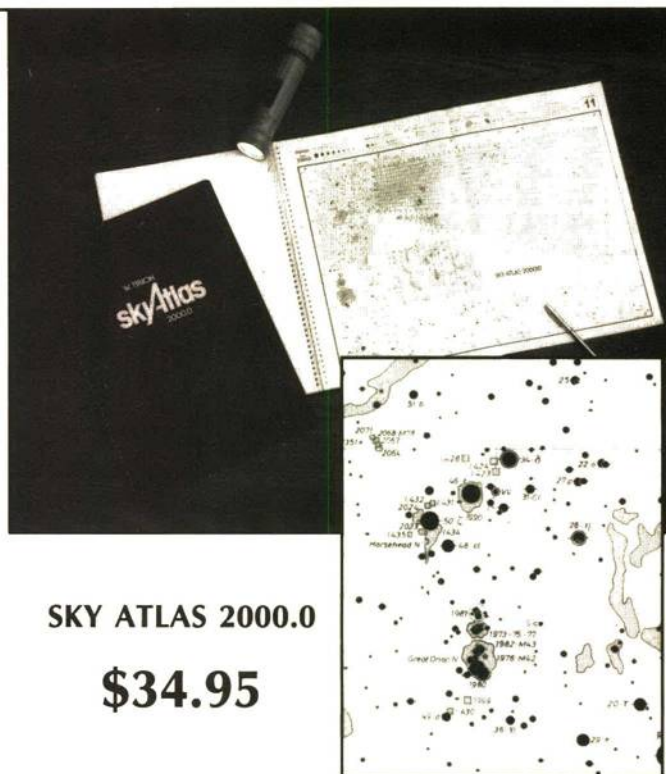
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But the arrival of the first Astronomer Royal, John Flamsteed, brought trouble for HR 483.

The third volume of Flamsteed's monumental *Historia Coelestis Britannica*, which appeared in 1725, contained not only Flamsteed's famous star catalogue but those of other prominent astronomers, including a catalogue by Hevelius. Hevelius' original star catalogue listed the stars in each constellation in roughly the order of their magnitudes, but Flamsteed rearranged Hevelius' 1,564 stars according to their right ascension and added a separate column to include their Bayer letters, since Hevelius had not included Bayer letters in either his catalogue or atlas.

While reordering Hevelius' star lists, the Astronomer Royal made a simple error. He made the fortieth star in Hevelius' list the thirty-eighth in order of right ascension, then erroneously assigned Bayer's letter Upsilon to it. Bayer's original Upsilon, HR 483, which corresponded to Hevelius' original 20 Andromedae, was renumbered by Flamsteed as Hevelius' 41 Andromedae and was left without a Bayer letter.

When Flamsteed prepared his own catalogue, the famous "Stellarum Inerrantium Catalogus Britannicus," which also appeared in Volume III of his *Historia Coelestis Britannica*, he carried forward this mistake. Flamsteed's 50 Andromedae, which corresponds to the renumbered thirty-eighth star in Hevelius' list, was mistakenly assigned Bayer's Greek letter Upsilon. This left HR 483, the original Upsilon Andromedae, without a Bayer letter.

HR 483 was then forced to endure an even greater indignity at the hands of the Astronomer Royal. Although Flamsteed had earlier observed this star, for one reason or another he inadvertently omitted it from his published catalogue. As a result, HR 483 was stripped of its name. Not only did it lose its Bayer letter, but it was not even assigned a Flamsteed number. *Sic transit gloria mundi!*

Four years after the appearance of his catalogue, Flamsteed's *Atlas Coelestis* was published. It was among the first atlases to identify stars with clearly marked Bayer letters. And sure enough, not only was the Upsilon Andromedae error repeated, but, since the atlas was based exclusively on the star catalogue, HR 483 was also omitted. Beautifully drawn, with equatorial as well as ecliptical coordinates, the atlas became enormously popular with astronomers. It was reprinted in 1753 and again in 1781.

And its error propagated viciously.

Translated as *Atlas Celeste*, the *Atlas Coelestis* was revised and updated in

France by the astronomers Pierre Mechain, a colleague of comet hunter Charles Messier, and Joseph-Jerome de Lalande. It went through various editions on the continent, the last in 1795, all with the same Upsilon Andromedae error. As a matter of fact, in his famous *Histoire Celeste Francaise* of 1801, Lalande copied Flamsteed's error into his own catalogue, noting that on the night of September 4, 1799, he observed Flamsteed's "50 [Upsilon] Andromedae." Lalande had earlier observed HR 483 on the night of December 19, 1797, but without realizing that it had once been called Upsilon.

The English astronomer Francis Wollaston made the same mistake. In his *A Specimen of a General Astronomical Catalogue* of 1789, he copied the Astronomer Royal's error by listing Flamsteed's "50. [Upsilon] Andromedae." He also listed HR 483, Bayer's Upsilon Andromedae, but referred to it simply as "Andromedae Hevelii 41," an indication that he used Flamsteed's renumbered copy of Hevelius' catalogue as his source.

The prominent Italian astronomer Giuseppe Piazzi repeated the error. In his Palermo Catalogue of 1814, *Praecipuarum Stellarum...Positiones*, he noted that his star I 119 was synonymous with Flamsteed's "50 [Upsilon] Androm." He also mentioned that his I 142 — the original Upsilon Andromedae, HR 483 — was synonymous with "Andr. 41 Hev.," an obvious hint that he, too, was using Flamsteed's edition of Hevelius' catalogue.

Why did this happen? Didn't anyone ever check Flamsteed's work? It appears that Flamsteed's stature had grown so great that few astronomers dared challenge his authority or the accuracy of his work. Like Piazzi and Wollaston, they felt sure that if they had Flamsteed's edition of Hevelius' catalogue, it was unnecessary to examine the original.

Most astronomers apparently did not even bother to compare Flamsteed's atlas with Bayer's. As a result, the Upsilon Andromedae error became deeply entrenched in the astronomical literature. The German astronomer Johann Bode, for example, copied Flamsteed's error into his famous atlas of 1801, *Uranographie*, an understandable mistake inasmuch as he had earlier prepared a German edition of the Flamsteed atlas. The error appears again in the *Memoirs*, Volume II, of the Royal Astronomical Society's "General Catalogue of the Principal Stars" of 1826; in Friedrich W.A. Argelander's *Uranometria Nova* of 1843; and in Eduard Heis' *Atlas Coelestis Nova* of 1872. Thus the error has been propagated to the present day.

The first to call attention to Flamsteed's error was the British astronomer Francis Baily. While searching through Flamsteed's papers in preparation for compiling a biography of the first Astronomer Royal, Baily discovered Flamsteed's mistake. When he completed the biography, which was published in 1835, he appended to it a revised edition of Flamsteed's catalogue, which included several hundred stars that Flamsteed had observed but omitted from the *Historia Coelestis Britannica*. Among these lost stars was HR 483. Baily assigned it No. 109, called it Upsilon Andromedae, and noted that this "is the star designated by the letter υ in Bayer's map; which I have here retained." At last, after a hundred years of neglect, HR 483 was to be restored to its rightful place in the heavens.

But HR 483 truly was an unlucky star. Baily died in 1844 while editing two large stellar catalogues and was, therefore, only able to partially complete its rehabilitation. In *The Catalogue of Stars of the British Association for the Advancement of Science* of 1845, star No. 480 was properly listed as 50 Andromedae without any Bayer letter. However, star No. 510 (HR 483) was also listed without a Bayer letter. Two years later, a revised edition of Lalande's *Histoire Celeste Francaise* was published in England and star No. 3055 (HR 483) was correctly identified as Upsilon Andromedae. The editors of this catalogue noted that Baily had completed work up to No. 7680 before his untimely death, and thus was able to correct Flamsteed's mistake.

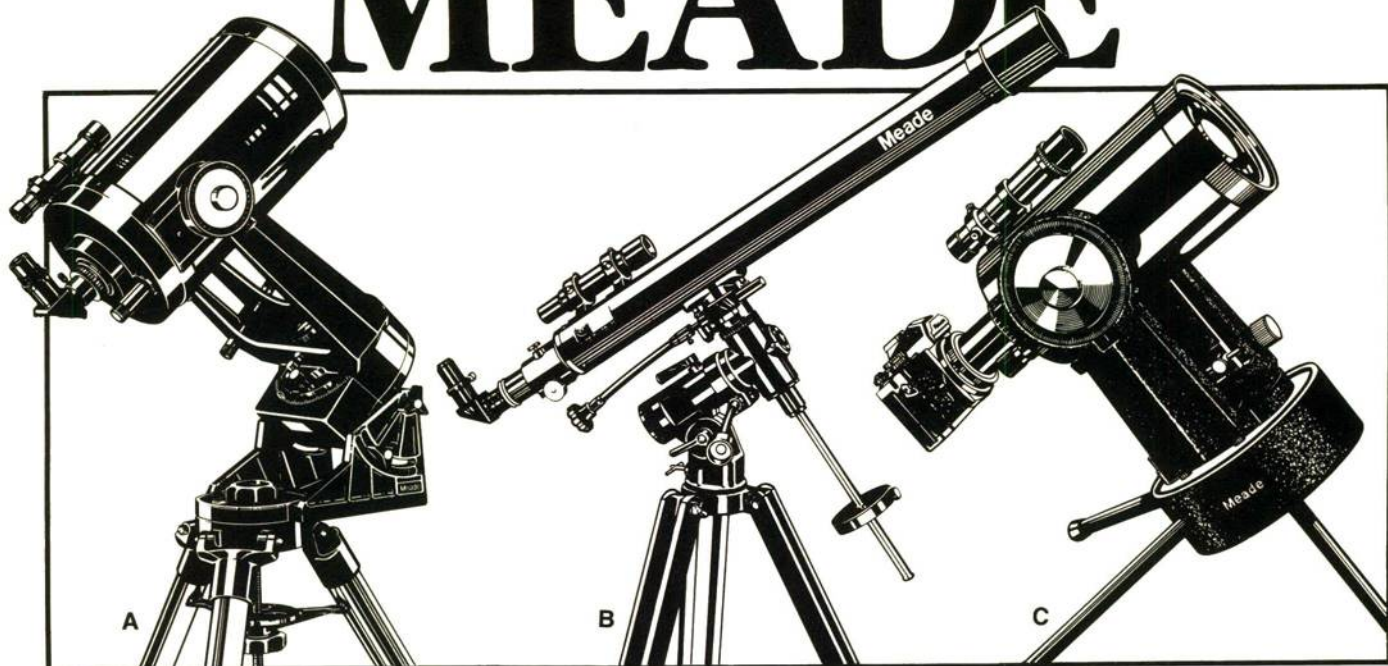
But by then it was too late — the error was too widely spread. Because HR 483 appeared under the wrong name in so many places, Baily's correction was overwhelmed. And except for Francis Baily, no astronomer from that day to this has sought to correct Flamsteed's error.

Astronomers and historians of astronomy, even the pickiest, should not be too critical of the first Astronomer Royal, however. Despite nearly overwhelming personal and financial problems, he made an enormous contribution to science, and his catalogue was unsurpassed in accuracy. He was a careful, meticulous worker who was constantly revising and reviewing his observations. In fact, he tried to delay the publication of the catalogue because he felt it was not yet ready.

Unfortunately, Flamsteed died before he considered his great work complete. Perhaps if he had lived a bit longer, he would have caught his error and preserved the name of HR 483, Bayer's lost star.

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Astronomy from Spacelab: An Interview with Dr. Loren Acton

Spacelab 2 was launched aboard flight 51-F of the Space Shuttle, the third flight of the Spacelab system. Scheduled for launch on July 12, 1985, the first launch attempt failed. Four seconds before lift-off, with the main engines already firing, the Shuttle computers detected a problem with a fuel valve and aborted the launch.

The second attempt, seventeen days later, was no less dramatic. After an apparently flawless take-off, one of the Shuttle's main engines shut down in flight when a faulty sensor reported that it was overheating. A similar problem with another engine sensor nearly caused the shutdown of a second engine and for a moment it appeared that the Shuttle was in serious trouble. On instructions from ground control, the astronauts overrode the second faulty sensor and continued up to orbit on two engines, dumping fuel from the smaller orbital maneuvering system rockets to reduce weight. The Shuttle finally settled into an orbit 315 kilometers high, 65 kilometers lower than originally planned.

Unlike earlier Spacelab flights, Spacelab 2 operated without a pressurized Spacelab module in the payload bay. Instead, the payload bay and part of the Shuttle mid-deck was occupied by a number of large experiments in astronomy, physics, and biology. Despite the launch difficulties, the mission was a resounding success. Although planned for seven days, Spacelab 2 was extended for one day to allow extra observations to be made.

John Davies, a space scientist at the University of Birmingham, England, spoke with Dr. Loren Acton, Spacelab 2 specialist, before the recent Challenger accident. Their conversation records one scientist/astronaut's experience in the pre-Challenger heyday of the Space Shuttle.

ASTRONOMY: Dr. Acton, before we talk about the flight itself, can you tell us how you became an astronaut?

Acton: Well, I've been a solar physicist for better than twenty years, and it was almost a natural evolution to get involved in the program during the Shuttle era when I could go along with the experiment and actually do the observing myself.

ASTRO: Could you say a little about your training for the mission?

Acton: Well, there are three aspects to this training business. There is the course work, which tends to be listening to briefings on various systems, reading the manuals, and learning how to operate the galley or the communications system. Those are

the things that you need to know just to live in space.

The next aspect, which for the payload specialists occurs over a period of several years, is helping to put the mission together. There are an infinite number of decisions that have to be made to make all of the scientific instruments play together. The crew plays a crucial role in helping the scientists and the NASA people make up the mission plan. It isn't really training, but you learn an awful lot in the course of doing it.

Finally, there are the simulations. When you take a slice of the mission and you go out and simulate it, that's when you find out if all your planning is really going to work. That is genuine training because you are learning to work with your colleagues and to follow the mission plan.

ASTRO: How long did the training take?

Acton: The total mission preparation goes on for years, in our case six or seven years, although the training from the books can be done in a couple of months, so it's not a big deal. The mission simulation depends on what your mission is. In our case this was very important and it took quite a lot of time.

ASTRO: Did you do any preparation for zero gravity?

Acton: I did take three rides on the Boeing 707, where they fly these parabolic flight paths and as you go over the top you get a few seconds of weightlessness — sort of. The weightlessness is not high quality. It depends on how well the pilot flies his trajectory. If he doesn't get it right you spend your time bashing into the ceiling or the floor. Other than that there was no weightlessness training at all.

ASTRO: What was it like when you went out to the Shuttle on the day of the launch?

Acton: It was a beautiful day. When we got there, nobody was on the launch tower except the crew and the three people who put us in. Everybody else had gone already to a safe distance. The tower was totally vacant, and we felt that we could have gone anywhere, done anything. It was so terrific that I let out a real yell of excitement.

ASTRO: So what were your reactions when the engines shut down just before liftoff?

Acton: I was really irritated about the whole thing. We had been preparing for this mission for a number of years. We were on the pad and the countdown was absolutely flawless. Then the main engines started. Because they

are off center, they push the orbiter toward the tower by about three feet when they start, and you can feel this motion. We could hear the countdown over our headsets, 7... 6... 5... 4... *ABORT.* I felt, "Hey, this can't happen to me. You guys can't do this."

Of course we took certain precautions in case we had to leave in a hurry. We unstrapped from our harnesses and got our personal emergency airpacks out from under our seats. If there's a fire or something these allow you to breathe and get out of the Shuttle efficiently, but it's still a 97-foot drop down to ground level.

But it turned out alright because we got to go to all the launch parties.

ASTRO: What about your feelings on the second launch attempt?

Acton: When we came back for the second launch, the crew was a substantially more sober bunch; the elation of that first attempt was not reproduced the second time. We were much more cautious.

Our caution was justified because we had so many problems the second time. For example, one of the gyros that control the solid rocket boosters failed, and it was necessary to set up backup software to control booster A from booster B and things like that. Then we had a problem with one of the computers, which we had to completely reload. I was convinced we would never launch but John Bartoe, who was also on our flight, said, "I think we're going to get off today," and eventually we did.

We got off alright and everything felt fine. The solids burned really well and everything was going according to schedule. Now, while everything is going well there's not actually all that much for the pilots to do, and so the people on the flight deck were talking about the view and this and that. Then, all at once, the thrust dropped off. We knew that we had lost an engine, the question was, was it one, two, or all three? Again I had this feeling of irritation, you know, "They can't do this to us. We still aren't going to make it into orbit."

If we'd had to land in Spain or some place like that it would have been a disaster. It would have been the fastest transatlantic crossing in history, but we would not have gotten the mission flown for years because of the time it would take to dismantle the payload, fly it back to the States, and put it all back together again. So it was an enormous relief when the word came up that we would abort to orbit.

ASTRO: Once in orbit how easy did you find it to adapt to zero gravity?

Acton: Relatively easy. I was uncomfortable in my stomach within ninety seconds and I stayed uncomfortable for about three days, but I didn't find it particularly difficult to adapt. We had

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talked about it a lot so I knew what it was going to be like. You don't try to move fast, you just take your time and do the various jobs you have to do.

ASTRO: What was your favorite aspect of zero-g?

Acton: I think my favorite part was just floating. Floating takes a bit of getting used to, and at first I found myself floating up and banging into the ceiling all the time. Then astronaut Story Musgrave, who has flown before, said to me, "You keep touching things, every touch moves you about, so stop touching things."

Once I got over the feeling that I had to keep touching things I quit floating up to the ceiling. By the end of the mission I would be eating my meals just floating about the cabin. Drifting around is a lot of fun.

ASTRO: When you were working were you able to see the results of the experiments coming in and react to what you saw straight away?

Acton: In some cases we could tell right away how we were doing and in others we had to wait for information from the ground. In the case of the solar telescopes, which was the real reason I was there, we had real-time information on how everything was going.

ASTRO: There were initially some problems with the Instrument Pointing System, which aimed the solar telescopes. Were you involved in troubleshooting these?

Acton: I was involved, very much involved, in fact. The IPS was a brand new system that had never flown before, and it was very complicated. Its real properties were never fully understood, so the payload specialists took a very active interest in it. We were able to work with the mission specialists, making suggestions about what to do, but it was really the folks on the ground who worked out the solutions. The system required software patches that were far beyond our ability to implement onboard.

ASTRO: What were your best moments during the flight?

Acton: I should point out that while you are working, the job almost fills your time. It was days — four days — before I had time to experience what I was doing. Then I suddenly realized, "Here I am in space!" and that was the peak from a personal point of view. From a professional point of view I think the best moment was when I saw the image of a sunspot stabilize on the TV monitor of our experiment. That meant that the experiment was functioning and the science was coming in.

ASTRO: What finally limited the length of the flight?

Acton: We ran out of hot sauce for my scrambled eggs. Seriously, in our flight we were limited by two things:

the supply of liquid hydrogen, which we burn in our fuel cells to produce electricity, and by the supply of fuel for attitude control. We were running against the red line on each of these right through the final day. But by conserving electricity and by the pilots being extremely careful and skillful at stretching out every ounce of fuel, we did get one extra day. The red line allows you sufficient reserves for another emergency day in orbit if you shut everything down and just stay alive to solve whatever the problem is keeping you up there, so we did still have our emergency reserve.

ASTRO: That's quite remarkable since you had to dump fuel during the launch.

Acton: Yes, we had dumped 5,000 pounds of fuel just to get into orbit. Now, the fuel was not actually burned

*"Hey, this can't
happen to me.
You guys can't
do this."*

to get thrust, it was done to offload that much mass so that the external tank would fall into the ocean instead of someone's backyard.

ASTRO: Did you get along well with each other during the mission?

Acton: You know, I can say that in eight days together in that extremely tense environment there was never a harsh word. That was because we had worked together and practiced together and come to know each other very well. We knew where the rough edges were and had learned to live with them. There have been crews where this was not the case, but in this mission everyone was pulling for the prime objective of doing good science.

ASTRO: Did you ever have any time to yourself?

Acton: Very little. By the time you prepare your meals and do all the little jobs that need doing, there is no leisure time other than an hour now and then. What I did then was go upstairs and look out of the window. I could do that without too much disruption. Everyone on board appreciated the need to look out the window sometimes.

ASTRO: How did you feel when it was time to prepare for re-entry? Were you glad to be coming home?

Acton: I was ready to come home. We had done as much science as we could do, the experience had been had, and the experience of coming home was to be looked forward to.

ASTRO: What was re-entry like?

Acton: The Shuttle flies with about the aerodynamic qualities of a brick,

and you don't get two chances to find the airfield, so everything has to be right the first time. Gordon Fullerton is such a super pilot that he set it down smoother than 90 percent of the airline landings I've been on. If it hadn't been for the change of noise level I don't think I would have known that the wheels had touched the ground.

Then, if your name is Loren Acton, as soon as the Shuttle rolls to a stop, you realize that there is something terribly wrong inside your head because the world is spinning round and round and round. It was about forty minutes before I could get my pins under me securely enough to walk off the spacecraft.

I had always wondered why it took the crew so long to get out of the Shuttle, I thought it had to do with technical issues like switching on cooling, but as a matter of fact they are waiting for the weakest fish among them to be able to walk. In our case that was myself.

ASTRO: Did it take long before you were back to normal?

Acton: By the end of the following week I had gotten over the effects, but it was an interesting experience readapting to normal gravity. In the evening I would be completely adjusted and I would think, "Well, I've finally got rid of that," and then the next morning I would wake up and the world would be moving again. It took a good week to get over the effects of being in orbit a week.

ASTRO: Now that your mission is over, what are your future plans? Would you like to fly again?

Acton: I would be willing to fly again if it made sense scientifically and operationally. If the training I've had could make a mission a lot cheaper to fly, and therefore we could have one that we otherwise couldn't, or if there was some reason why it made sense for me to fly rather than someone else, I would go, but I don't covet it. There are a lot of people who ought to have this experience.

ASTRO: It's always been argued that scientists should fly with their experiments to make sure they get done properly. After your experience on Spacelab 2 do you think this has been demonstrated?

Acton: We probably achieved more good, solid results in less time because we had scientists on board. On the other hand, there were a number of experiments on the orbiter that were controlled almost exclusively from the ground. It's not a question that can be answered in general.

ASTRO: Finally, if I asked you to sum up your flight in one word, what would it be?

Acton: Adventure.

John Davies
Birmingham, England

ASTRONOMY

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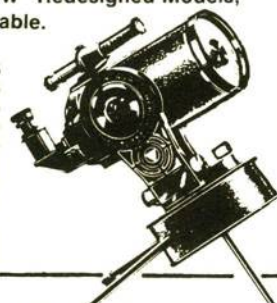
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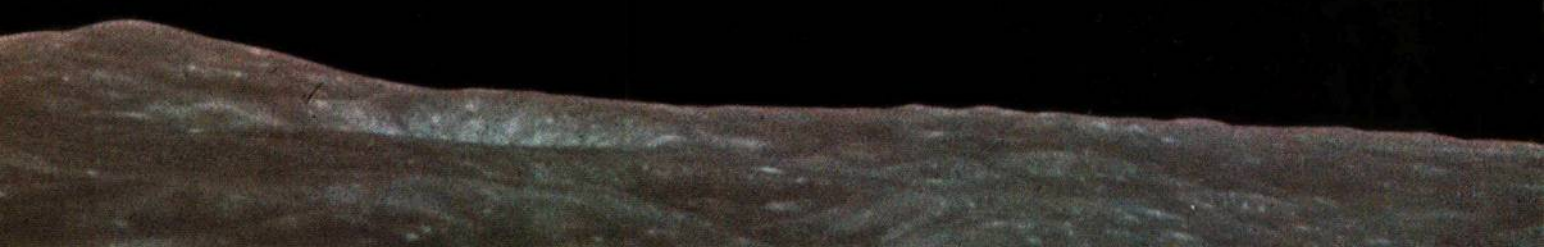
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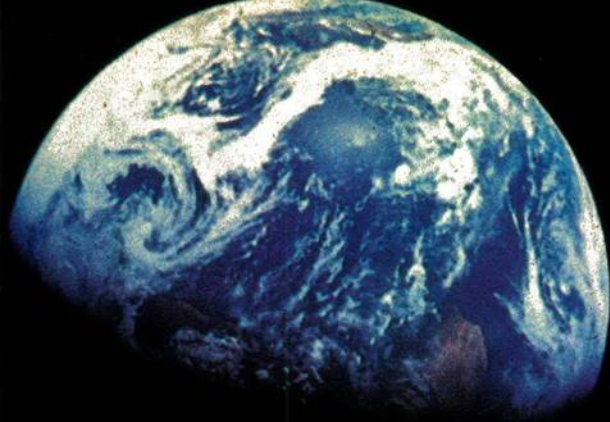
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Sir / Thanks for the new wrapper on ASTRONOMY. I appreciate your thoughtfulness.

Roscoe J Pratt
Jackson, MI

Sir / You-all come back again next month with our ASTRONOMY packaged stylishly, practically, progressively, and pretty perfect, ya hear.

Don & Alice Nigre
Denver, CO

Sir / I just received my August issue of ASTRONOMY magazine and, because of your new plastic wrapper, it arrived in excellent shape. I've always felt ASTRONOMY was worth the cover price, but now it is worth even more. Good going!

Steven D. Redd
Missouri City, TX

Sir / It was with jubilation that I received my August copy of ASTRONOMY in mint condition. I have received uncounted issues of torn, wrinkled, and wet magazines and have become accustomed to less than adequate mail handling.

My appreciation for the new plastic mailer. You've made a great stride toward "mail-proofing" your magazine.

Ron Dawes
San Antonio, TX

— We appreciate your enthusiasm for the new plastic wrapper. Even with it, however, some copies did not survive the journey from the printer to your mailbox. Although we can't do much about postal service, our long-standing policy is that if your copy of ASTRONOMY arrives mangled, we'll replace it promptly and free of charge.

The Inflated Cost of Astronomy

Sir / "Astronomy is looking up." Ever heard that phrase before in reference to the healthy state of the science today? Well, even if one climbs on a ladder, the price of astronomy can also be found by "looking up." Prices during the Halley-hype season were driven out of realistic proportions. Thirty dollars, at discount prices, for something as simple as an eyepiece adapter? Let's be realistic: an eyepiece adapter is a simple 3-inch piece of metal with two different O.D. and I.D. dimensions and a set screw at one end. Two years ago a good orthoscopic eyepiece went for \$27; now they list for \$80!

Come on, guys. Let the high costs go back into the depths of space with Halley's Comet. Let's get prices "down to Earth" again so those of us who enjoy astronomy can afford to pursue our interests to both scientific and aesthetic ends.

John H. Hanson
Westerly, RI

Charles F. Capen, 1926-1986

Sir / Chick Capen, a frequent contributor to your pages, was my mentor, hero, and a close friend. In my twenty years of astronomical research I have met only one other professional who was so completely devoted to research for its own sake rather than for personal gain. In recent years he turned down prestigious positions at the Mauna Kea and Lowell observatories because he would not have had enough time for observing and his own research.

Indeed, Chick was the last of the great observational astronomers. Although we had observed together many times over the years, Chick always had some new trick to show me or some new description of what we were seeing. His knowledge of

Mars and its observational history was encyclopedic, but he imparted this knowledge in such a manner as not to make the student feel inferior. He was a most gentle teacher.

Chick loved teaching amateur astronomers and felt very strongly that amateur contributions are still important to astronomy. Despite the fact that he was an internationally respected professional, he still considered himself an amateur at heart, and his work with the Association of Lunar and Planetary Observers was most important to him. In fact, of his many awards he prized the A.L.P.O. Walter H. Haas award the most. His last wish was that his work with A.L.P.O. and with Mars be continued.

We shall all miss this gentle man.

Donald Parker
Coral Gables, FL

Protect Your Vision

Sir / The comments by Steve Mensing (In Focus, April 1986) on the hazards to binoculars and closed-tube telescopes when they are used to project a solar image are well taken.

However, Steve's last paragraph implies that it may be safe to glance at the Sun with binoculars fitted with aluminized Mylar filters. Be careful there! That glance could shorten the useful lifetime of your retinas.

Most filters are worse than useless for eye protection, even in just glancing at the Sun. The reason is that they attenuate light in the visible portion of the spectrum but not in the infrared and ultraviolet. The result is that the pupils dilate and allow more of the infrared and ultraviolet to flood the retina. Both of these kinds of radiation can harm the photosensor walls of the retina with a delayed reaction time measured in years.

Do not look directly at the Sun or at reflections of direct sunlight unless you

are sure that the optics in front of your eyes are opaque to infrared and especially ultraviolet light at wavelengths less than about 400 nanometers. The filters you need are not cheap, but they may save your eyesight.

Norm Peterson
Santa Monica, CA

Halley Was A Good Show

Sir / Over the past few months I've heard people complain about Comet Halley's show. I have seen this in both articles and cartoons.

I thought Halley gave a spectacular performance. I was overjoyed when I first picked it up in early November. I didn't care that it appeared faint and fuzzy because I had seen the celestial event that had inspired men for over 2,000 years. As it grew brighter, I also grew in my knowledge of the sky.

Astronomers' photographs of Halley, from Earth and from comet probes, were the best photographs of a comet ever taken. We now know more about comets than we ever knew before, and consequently we know more about our solar system. In this respect, Comet Halley was not a failure this time around, but a rousing success.

Nathan D. Davis
Auburn, AL

Re-name Nemesis

Sir / The popular theory that a dwarf-star solar companion called Nemesis caused periodic biological extinctions on Earth has a serious nomenclature flaw. The International Astronomical Union requires each body in solar orbit to have different, unique names. Since the asteroid 128 Nemesis, discovered November 25, 1872, from Ann Arbor, Michigan, preempts the name Nemesis, the dwarf-star will need an alternate name if it is ever discovered.

Walker Vaning
San Rafael, CA

Don't Move the RGO

Sir / I am writing to express my concern and alarm at the announced closing of the Royal Greenwich Observatory at Herstmonceux Castle in East Sussex (see *AstroNews*, p. 94).

Although only part of the facility is to be moved to Cambridge, the full operational capability will almost certainly be affected. The great instruments housed with workshops, research units, the satellite ranging device, and the historic library are together on one site that provides vital information for professional and amateur astronomers around the world.

The setting has not been disturbed by light pollution to the extent of other

sites in the British Isles. The Sir Isaac Newton Telescope, now located in the Canary Islands, can be operated from Herstmonceux using the Starlink computer system (see "British Astronomy Reaches New Heights on La Palma," April 1985).

The RGO Time Department has played a vital part in determining international atomic time as well as a leading role in evolving a system of intercomparison of standards and publishing results. Research and development also continues in the field of optical astronomy, providing a service to astronomy with a worldwide reputation for excellence.

The Royal Greenwich Observatory at Herstmonceux acts as a nucleus for astronomy in the United Kingdom, bringing together professional and amateur astronomers. It would be a catastrophe to British astronomy if it was to close.

Andrew P.B. Lound
West Midlands, England

Clear Sky Priority

Sir / So clouds don't bother certain Oklahoma City astronomers, eh? (In *Focus*, June 1986) What visual astronomer would go to a star party anywhere, anytime, *not* expecting clear skies?

I invite Mr. Pearson to spend a winter in northeastern Ohio. After six to seven months of what we politely call the "lake effect," he'll quickly realize the priority clear skies have when planning to spend time and money on a distant, isolated star party.

Edward F. Hafner
Astronomy Club of Akron, Inc.
Akron, OH

Ooops!

The correct name of the winner of the "Best Astrophoto" contest in the August 1986 issue is Victor Rogus.

In the June 1986 issue, the photograph on page 57 should have been credited to Michael J. Himmes and Matthew R. Malloy.

Behind the Scenes

Our Buyer's Guide Issue

ASTRONOMY is pleased to present our second annual Buyer's Guide issue, consisting of the 1986 ASTRONOMY Guide to Telescopes and the ASTRONOMY Equipment Directory. The Guide to Telescopes will help you select the telescope that best meets your needs. This year's guide includes a new section on the goodies available in the booming area of astronomical accessories. It's probably not necessary for me to point out that this is a good time to buy a telescope. As the wave of Halley-mania recedes, we're seeing telescopes priced at 50 percent of list.

The Equipment Directory, prepared by our hard-working advertising department, puts you in touch with the people who supply astronomical equipment. The Directory is bound into the center of the magazine. To separate it, gently pull it away from the staples that bind the magazine, then bend them down again. The Directory will stay together after you've removed it. We would appreciate hearing your comments on our Guide to Telescopes and Equipment Directory so that we can bring you an even better Buyer's Guide next year.

Apart from the Guide and Directory, this issue is a call to get out under the stars. Whether you try photography, as John Waugh did;

find a few of the planetaries Charles Juhnke has listed for you; learn how to take well-guided exposures, as Barry Gordon suggests you should; or simply step out to see the wandering planets and the stars of autumn with Robert Burnham's guidance, we know you'll enjoy "doing" astronomy.

On the cloudy nights, curl up with the feature articles. You can get lost in a black hole or contemplate the many uses astronomers have found for the entire sky captured on Schmidt camera plates and the new sky survey now in progress. Finally, we trust that reading about stellar populations and the different types of star clusters will stimulate you to wider reading and deeper appreciation of the universe.

As for our old friend Comet Halley, we've prepared a detailed finder chart for you on pages 116 and 117. This autumn and winter the comet is located in Crater's cup where, with the aid of a fairly large telescope, it should be fairly easy to follow as it recedes into space.

Sincerely,



Richard Berry
Editor-in-Chief

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#114 2.4" Altazimuth	35X, 50X, 72X, 100X	7°12'	60 mm, f/15	6X—24 mm, 6°22' field	34½ in.	58 in.	16 lb.
#128 2.4" Equatorial	35X, 50X, 72X, 100X, 129X	7°12'	60 mm, f/15	6X—2 mm, 6°22' field	34½ in.	60 in.	24 lb.
#140 3" Altazimuth	48X, 67X, 96X, 131X, 171X	4°20'	75 mm, f/16	8X—30 mm, 4°22' field	47 in.	59 in.	23 lb.
#142 3" Equatorial	48X, 67X, 96X, 131X, 200X	4°20'	75 mm, f/16	8X—30 mm, 4°22' field	47 in.	59 in.	46 lb.
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#150 4" Altazimuth	60X, 83X, 120X, 167X, 214X, 250X	3°22'	100 mm, f/15	10X—40 mm, 2°54' field	63 in.	64 in.	50 lb.
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A Delightful Dozen of Planetary Nebulae

by Charles M. Juhnke

Gazer's
Gazette

Among the lovelier and more compelling objects of the heavens are the pale, bluish green disks that in telescopes appear as ghostly replicas of the planets. Because of this visual similarity — and only because of it — these objects are called planetary nebulae.

Over 1,000 planetary nebulae have been catalogued in our galaxy. Statistical estimates based on extragalactic surveys tell us that there may be as many as 10,000 more in the Milky Way. They are relatively small, averaging a light-year or less in diameter, but are quite bright for their sizes.

There are, however, no planetaries visible to the unaided eye and only a handful are recognizable in telescopes with apertures smaller than 4 inches. Even so, it is challenging to hunt for these ghostly objects and is an excellent test of instrument and eye.

Although much about the development of planetary nebulae is still unknown, astronomers are certain these objects represent the end of a star's life as a giant after roughly 10 billion years of being a "normal" star of about 1.2 solar masses. Essentially, the gaseous part of a planetary nebula, the part that we see as a ring or bubble, is the distended shell of a red giant that has been blown away by stellar "winds" from the exposed hot core of the progenitor star. This shell, representing about 20 percent of the original star's mass, expands from the star at a speed of 20 to 30 kilometers per second.

The progenitor star, located at the center of the expanding shell of gas, typically is a white dwarf with temperatures near 50,000 K, although some get as hot as 100,000 K. A star this hot emits large amounts of ultraviolet radiation, which is absorbed by the atoms in the outer gas shell and re-emitted as visible light in a process called fluorescence.

What is the ultimate fate of a planetary nebula? As demonstrated by photographs of the Ring Nebula taken forty years apart (and by spectral analysis), the gas shell continues expanding from the central star.



The Owl Nebula, M-97, in Ursa Major is one of the nearest planetary nebulae. Although its low surface brightness poses a challenge to observers with small telescopes, it can be seen in a 3-inch reflector under dark skies as a round patch of diffuse, gray light. Photo by Leo C. Henzl, Jr.

After some 30,000 to 50,000 years — a brief moment in astronomical time — the atoms of gas become too diffuse to be ionized by the central star; the gas stops glowing and spreads itself through interstellar space. Over the next few billion years, the central star cools until it fades into a mass of dark, degenerate gas.

Planetary nebulae come in a variety of magnitudes, shapes, and sizes, depending on the luminosity of the central star, age of the nebula, and its distance from Earth. Many of the differences in the brighter planetaries can be discerned in relatively small telescopes. To get you started observing, here are a dozen of the brightest planetaries visible in telescopes with 6- to 8-inch apertures. A few, such as the Ring and Dumbbell nebulae, can be glimpsed from a suburban site; others such as the Helix Nebula require a fairly dark sky.

Most planetaries respond well when

viewed through a light pollution filter (LPF) or "nebula filter," especially if your site is badly light polluted. For those planetaries with small apparent diameters — especially those smaller than 20 arcseconds — flip the nebula filter in and out of the viewing field between eye and eyepiece to bring out the planetary's nonstellar, "fuzzy" characteristics. Even if you don't have a filter handy, most of these are bright enough to enjoy and compare.

NGC-246

We begin in the constellation Cetus and find the intrinsically smallest planetary on our list, NGC-246. Its diameter is less than 0.07 parsec. However, since it is only about 400 parsecs distant, it has one of the largest apparent diameters of the bright planetaries. Unfortunately, this makes NGC-246 too faint an object for anything smaller than a 3-inch telescope under a dark sky.

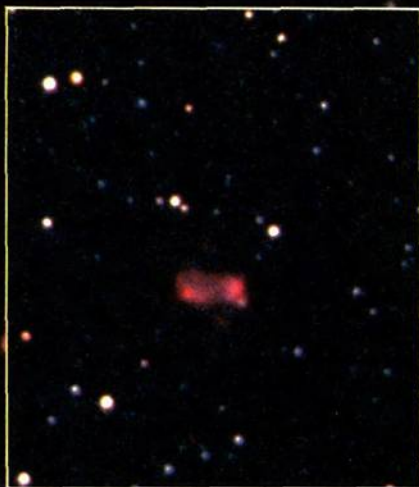
NGC-246 is positioned at the southern tip of an equilateral triangle formed by itself, Φ^1 (ϕ^1) Ceti, and Φ^2 (ϕ^2) Ceti. If you are viewing with a 6-inch or larger scope, try to locate the 12.8-magnitude galaxy NGC-255, half a degree to the north-northeast.

M-76

This planetary has two separate designations in the *New General Catalogue*, NGC 650/1, because William Herschel thought it was two separate objects. This confusion remained until modern astrophotography proved it was a single planetary nebula. In photographs taken through small telescopes, M-76 exhibits a dual-lobed shape similar to that of its big brother M-27, the Dumbbell, thus earning it the name the "Little Dumbbell" nebula.

At photographic magnitude 12.2 (visual magnitudes are nearly one magnitude brighter) it appears as a bar of hazy light in 6-inch telescopes. It is a beautiful sight in an 8-inch scope, with a slight indentation visible in the middle.

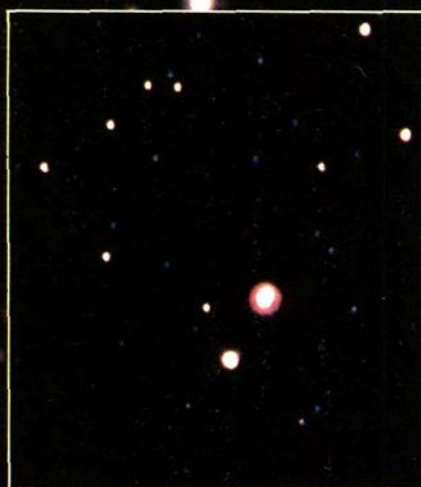
To locate M-76, start at Φ (ϕ) Persei near the Cassiopeia border then move



M-76 in Perseus is also known as the "Little Dumbbell Nebula." Its compact elongated shape can be seen in a 6-inch reflector using moderate magnification. Photo by Jack Newton using a 16-inch f/5 reflector and a 14-minute exposure.



NGC-246 is a large, bubble-shaped planetary that appears as a faint ring in 8-inch telescopes. This 40-minute exposure on Fuji 400 film was made with a 17.5-inch, f/4.5 reflector through a Deep-Sky filter. Photo by Jack B. Marling.



The Eskimo Nebula, NGC-2392, appears as a fuzzy star in small telescopes. Photo by Jack Newton. Below: The Dumbbell Nebula in Vulpecula is one of the brightest planetaries visible in small telescopes. Photo by Jack B. Marling.





nearly a degree north and a third of a degree west.

NGC-2392

Located 1.8° southwest of Mu (μ) Hydrae, the appearance of NGC-2392 in photographs and large telescopes is that of a face surrounded by a faint fringe of fur. Thus it has been dubbed the "Eskimo nebula." This title seems all the more appropriate since the best time of year to view NGC-2392 is during winter. The Eskimo is on the eastern side of the constellation Gemini, $40'$ southwest of 63 Geminorum. Those using 6- to 8-inch telescopes at high magnifications will see a small, bright disk, but the facial features and the blue-green color are visible only in telescopes of 16 inches or larger.

NGC-3242

Because NGC-3242 displays a hazy disk similar in apparent size to Jupiter, it is known as the "Ghost of Jupiter." In spite of its haziness and its great distance of 0.8 kiloparsec, this is a bright (magnitude 8.6) and interesting object. A 6-inch telescope shows the pale blue disk; larger instruments (16 inches or greater) reveal a hint of an outer ring as well as more of its inner structure.

M-97

This is the famous "Owl Nebula," listed as 3587 in the *New General Catalogue*. Located just under the bowl of the Big Dipper, 2.5° southeast of Beta (β) Ursae Majoris, it is visible nearly every night of the year for northern observers. Unfortunately, the owl-like eyes are only visible under very dark, transparent skies using at least an 8-inch scope and a nebula filter.

M-97 is one of the nearest planetaries. Coupled with an actual diameter of 1 parsec, these factors give it a large apparent size and low surface brightness, making this a difficult object for small telescopes. Still, even a 3-inch scope reveals the round, smokey patch of light under

good seeing conditions.

My first observation of this planetary was by accident. I was using a 3-inch Newtonian and had been observing M-108, a spiral galaxy located $45'$ to the northwest of M-97. From there I began scanning the region when I suddenly came across a vague patch of light. Of course I didn't even consider the possibility that it was M-97 because I had heard and read that to even glimpse the Owl Nebula required at least a 6-inch telescope. I checked my star maps and found that the only objects in this area were those I had already accounted for . . . and M-97.

Next, I moved the telescope in the direction of M-108, assuming that I was aimed at M-97, and the galaxy came into view. I reversed directions and again came across the mysterious patch, precisely in the same position held by M-97 in the atlas. Although it was faint and featureless, at least I gained valuable insight into the true limitations of a 3-inch reflector.

NGC-6543

The brightness of this object's central star (about 11th magnitude) gives this nebula the name "Cat's Eye Nebula." However, since the nebula has a small apparent diameter, the outer shell has a high surface brightness, which overwhelms the central star somewhat, making it more difficult to see. Smaller telescopes and moderate magnification show this diminutive but bright disk in Draco just south of a line between, and two-fifths the distance from, Zeta (ζ) Draconis to Delta (δ) Draconis. Larger telescopes (16 inches) are needed to show the whorls of this multi-ringed planetary nebula. This structure, also seen in other planetaries, is the result of multiple layers of gas being shed by the central star. Like M-97, NGC-6543 is circumpolar in the northern sky.

The Helix Nebula in Aquarius has a large apparent diameter and requires a dark sky and low magnification to see. Eight-inch telescopes reveal a faint, featureless disk that is best seen through a nebula filter. This 55-minute exposure by Jack B. Marling was made using a 17.5-inch reflector and a Deep-Sky filter.

The Cat's Eye Nebula is also historically significant. It was the first planetary nebula to be observed with a spectroscope. The resulting emission lines proved once and for all that planetary nebulae are truly gaseous shells rather than aggregates of unresolved stars.

M-57

M-57, which also carries the designation NGC-6720, is the beautiful and famous "Ring Nebula." This object is not only one of the best planetary nebulae to observe, it is a classic among all celestial objects. Its apparent size of 70 by 60 arcseconds and 9.7 magnitude makes it bright enough even for 2.5-inch instruments. My old 3-inch reflector just shows the darkened hole in the center of the ring, if I use averted vision (looking just to the side of an object while still seeing it).

The "ring" we see is actually a spherical shell. The annular form in this and other similar objects is an optical illusion resulting from the total amounts of material along our line of sight. We see the greatest amount of gas when we look at the edges of the shell and the least at its center, because we have less gas to look through.

Aside from its beauty, another factor that contributes to its fame is its prominent position high in the northern sky during the warm summer months. It is conveniently nestled between Gamma (γ) and Beta (β) Lyrae, about two-thirds the distance from Gamma to Beta. This arrangement makes the "Ring Nebula"

one of the easiest of all deep-sky objects to locate. Most observers will be able to see the pale blue-green disk surrounding a darkened area; larger telescopes will brighten the inner edge of the ring and show a distinctly oval shape. If you're thinking of starting a search for deep-sky objects, the Ring Nebula would be an excellent place to begin.

NGC-6826

Another summer planetary nebula is NGC-6826, referred to as the "Blinking Planetary" because the central star seems to blink off and on when one looks directly at it and then to its side — an effect of averted vision. The "Blinking Planetary" is similar in size and magnitude to NGC-6543 and is easily located in Cygnus less than 30' east of 16 Cygni. (If you have an equatorial mount, try placing Delta (δ) Cygni in the field of view and then, without changing right ascension,

actual size of the "delightful dozen" with a diameter of 0.8 parsec. At a distance of 300 parsecs, it is our eighth-closest planetary nebula. These two factors, combined with M-27's high surface brightness, make it the most visible of the planetary nebulae. Just about any optical aid will show at least a smudge of the nebulosity. Those with 8-inch and larger telescopes might try to glimpse M-27's 14th-magnitude central star.

NGC-7009

NGC-7009 is found in Aquarius about 75' west of Nu (ν) Aquarii. It also forms the northeast corner of a flattened triangle made with the globular cluster M-72 and the small star group M-73. Because this planetary shows faint extensions on each side of its disk, it reminded the great Irish observer, Lord Rosse, of the planet Saturn; thus, NGC-7009 carries the name Saturn Nebula. Though it is quite bright, smaller

about half that of a full Moon, makes it the largest planetary in angular diameter. However, because of its size, the Helix has a very low surface brightness. This makes it much harder to see than its magnitude might lead us to believe.

NGC-7293 is a challenge in 6- and 8-inch scopes. Wait for a night of dark, clear skies, use low power and averted vision, and you'll find it 75' west of Upsilon (υ) Aquarii.

NGC-7662

In the northern reaches of Andromeda some 30' south-southeast of 13 Andromedae, lies the final object on our tour: NGC-7662. The great brightness of the nebula is again the result of its small apparent size. A 10-inch telescope will show the scalloped edge of the disk. It is smaller than the Owl Nebula and the chances of seeing a disk rather than a point of light are decidedly worse if you're

TWELVE OF THE BEST PLANETARY NEBULAE

Object	R.A.(2000.0)	Dec.	Con.	Size	Mag.	Mag.*
NGC-246	00h 47.0m	-11° 53'	Cetus	225"	8.0	11.9
NGC-650/1(M-76)	01h 42.4m	+51° 34'	Perseus	65"	12.2	17.0
NGC-2392	07h 29.2m	+20° 55'	Gemini	13"	9.9	10.5
NGC-3242	10h 24.8m	-18° 38'	Hydra	16"	8.6	12.0
NGC-3587 (M-97)	11h 14.8m	+55° 01'	Ursa Major	194"	12.0	15.9
NGC-6543	17h 58.6m	+66° 38'	Draco	18"	8.8	11.4
NGC-6720 (M-57)	18h 53.6m	+33° 02'	Lyra	70"	9.7	14.8
NGC-6826	19h 44.8m	+50° 31'	Cygnus	30"	9.8	10.4
NGC-6853 (M-27)	19h 59.6m	+22° 43'	Vulpecula	350"	7.6	13.9
NGC-7009	21h 04.2m	-11° 22'	Aquarius	25"	8.3	11.5
NGC-7293	22h 29.6m	-20° 48'	Aquarius	769"	6.5	13.5
NGC-7662	23h 25.9m	+42° 33'	Andromeda	20"	9.2	13.2v

Magnitude is total photographic magnitude; magnitude * is photoelectric V magnitude of the central star; "v" denotes variability.



The Ring Nebula.
Photo by Jack B. Marling.

move northward in declination about 5.5°.) A 6- or 8-inch telescope will show the disk, but greater aperture is required to show any of the structural details of this hazy oval.

M-27

Bringing M-27 into your field of view after observing the fainter planetaries is startling. Positioned in Vulpecula, a little over 3° north of Gamma (γ) Sagittae, this planetary is another classic deep-sky object. This is the Dumbbell Nebula, so named because of its dual-lobed shape, similar to the weight-lifting apparatus. It appears as a chubby bar with enlargements on its ends and, like M-76, shows no ring.

The Dumbbell is the second largest in

instruments show just an oval patch of light. Under a dark sky, and with the aid of a nebula filter, 8-inch telescopes at high magnification will show hints of the earlike extensions that, for the planet Saturn, are referred to as ansae.

NGC-7293

Located in the southern portion of Aquarius is the famous Helix Nebula. If there was a book of records for planetary nebulae, the Helix would be included in it more than once. In actual size it ranks above average for planetary nebulae with a diameter of nearly 0.7 parsec. Because it is only about 140 parsecs from Earth, it is our closest planetary. Its apparent magnitude of 6.5 is the brightest of any planetary nebula; and its apparent size,

using an aperture of less than 3 inches. However, it couldn't hurt to go out on a clear fall night to see what you can of NGC-7662.

After you've taken the opportunity to view and study some or all of these planetary nebulae, try a little thought experiment: Imagine yourself in the eighteenth century; you are the first, or among the first, to discover one of these ghostly disks with your present-day, state-of-the-art telescope. What would you have called them?

Charles M. Juhnke is an active deep-sky observer and teaches observational astronomy for community education in St. Cloud, Minnesota.

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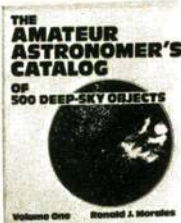
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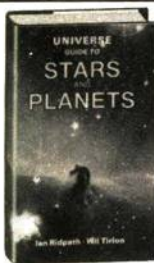
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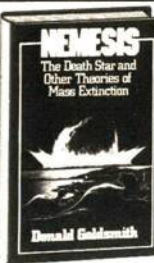
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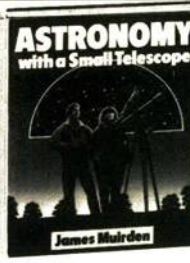
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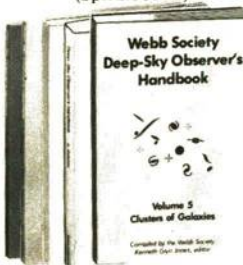
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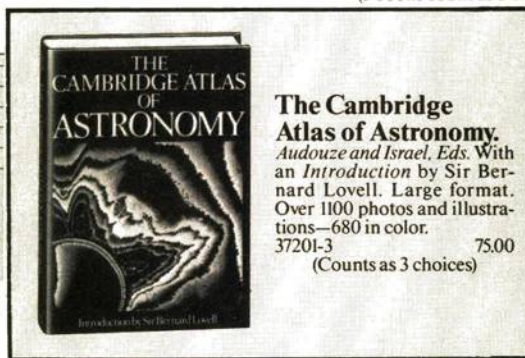
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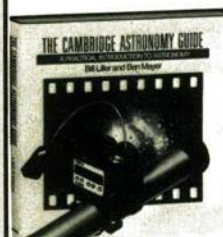
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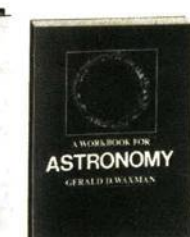
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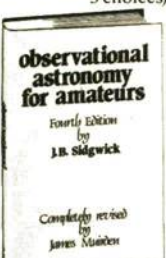
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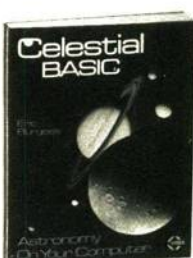
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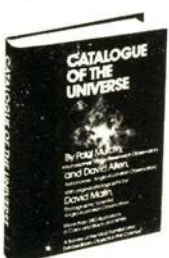
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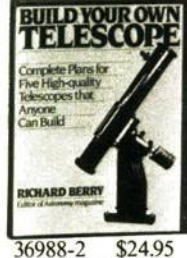
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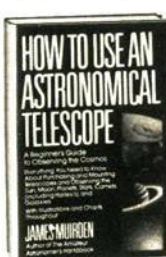
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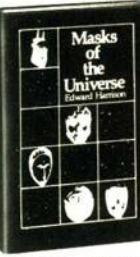
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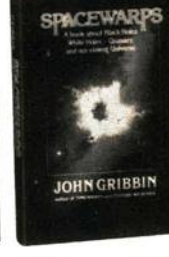
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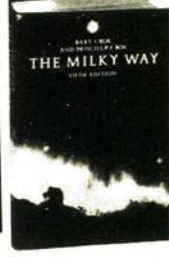
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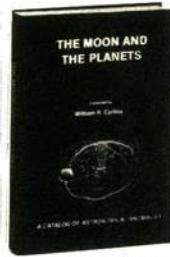
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Reviews

The Cambridge Astronomy Guide

William Liller and Ben Mayer
176 pages, cloth, \$24.95
Cambridge University Press (1985)

The *Cambridge Astronomy Guide* is a curious work and certainly the most unusual introduction to amateur astronomy I've ever run across.

To begin with, it is presented in chapters that alternate back and forth between the two authors. Mayer, an enthusiastic and experienced amateur astronomer, writes the odd numbered ones; Liller, a professional astronomer, takes care of the even ones. If Mayer's voice is that of a newly star-struck Everyman, Liller's is that of the sober scientist explaining the fundamentals of the subject.

The second way in which the book is unusual is its photography-oriented approach. Does it begin with the sky and celestial sphere? Constellations? Stars and planets? Not at all. Mayer gets you into astronomy via your camera and fast film, taking star trail photos of the sky. The formal framework of sky directions comes much later, after you've learned how to process your own film, in fact.

The style is delightfully candid. Mayer admits at the outset that he broke one of his primary rules — don't buy a telescope right away — because he wanted to snoop on his bikini-clad neighbors at their poolsides! It wasn't until cool weather drove everyone indoors that he turned the telescope skyward. Liller, for his part, takes you to Cerro Tololo observatory on a Chilean mountaintop for a night's run on a 4-meter telescope.

The main subjects covered are choosing a telescope and learning your way around the sky. The reader is introduced to the various types of celestial objects and is told what can be seen and how to make scientific observations. Toward the end of the book high-tech subjects such as closed circuit TV and photoelectric photometry are discussed. Mayer finishes with a year's "calendar," which spotlights one deep-sky object per month and includes a color

photo of it. An appendix lists books, periodicals, and equipment suppliers' addresses.

Running throughout the text like the subplot of a novel is Mayer's collection of clever homemade gadgets. For example, using plywood, a universal ball-head, and a small synchronous motor, you can take his plans and build a simple camera tracker for making untraced sky photos. And he describes his PROBLICOM, a device that lets you compare two film frames to discover if anything has changed between them. There's also a timer, built from a mousetrap and an alarm clock, for automatically shutting off exposures.

As I read the book a mental image of what the authors were doing slowly took shape. First one author and then the other was leading me by the hand here and there in the subject, with Mayer usually pointing out wonderful things I could do with very little equipment — things I, the inexperienced layman, could do *tonight*. Liller would then come along and fill in the scientific side. Then it's back to Mayer for a fast run to a different corner of the field where another astronomical goodie awaited.

It's fair enough to ask if this unorthodox approach works, but it's important to draw a careful distinction between an instructional method that fails and one that a reviewer is personally unsympathetic with. For better or worse, I tend to think in linear patterns and prefer to explore any new interest systematically. I grumbled over the authors' rambling approach because it meant readers had to do a lot of backtracking to fill in details. It also made retrieving specific information out of the book difficult, despite a good index.

On the other hand, I've met many people who excel in the "mosaic" approach to learning. They pick up bits and pieces from all over and fit them into a mental pattern that develops as they explore. Though I found the book's way of teaching me backyard astronomy was scattershot, I recognize that Mayer and

Liller eventually provide all the basic information. Someone exploring in "mosaic mode" would probably revel in the book's loosely structured delivery.

I think, in the end, this is a book whose flavor is so distinct that you'd be wise to sample it carefully in a library or bookshop before buying it. Many will find its organization confusing, but those for whom its approach is *simpatico* will treasure it greatly. *Robert Burnham.*

Observe Meteors

David H. Levy & Stephen J. Edberg
56 pages, paperback, \$5.50
The Astronomical League (1986)
[publisher's address: 1719 N St. N.W., Washington, DC 20036]

Like many backyard astronomers, I've done lawn-chair time. I've slapped at bugs while holding tired eyes open to catch the swift streak of a meteor. But somehow the grand plans of adding my mite to science, forged in a white heat of enthusiasm during daylight, seem to crumble around 3 a.m. Regular observing is wholly different. There you can pack it in by 11 p.m. if it's a work night or if you poop out. But meteors? They don't even get *going* until after midnight.

Yet on reading Levy and Edberg's book I felt the pull of meteor-watching again. And I realized why I'd found it so hard before to keep the interest going when both body and spirit began to wilt. For one thing, I had done my observing alone. Levy and Edberg stress that observing in groups is better for several reasons. First, you can cover the sky adequately so that few naked-eye meteors escape notice. Second, it's easier to maintain a sense of purpose and alertness when there's a group, especially if there are enough people in the group to spell each other. (I well remember the Perseid vigil in which one deranged friend kept several of us awake by playing tape-recorded Goon Shows for four hours straight.)

This book is a good manual for anyone

intending to make more than casual observations of meteors. It begins with an overview of meteor astronomy, explaining what meteors are and detailing the ten major annual showers. A section on planning tells how to recognize when to start observing a shower and when to quit or not bother (due to moonlight, for example). It includes "game plans" for single observers as well as for groups of five, ten, and fifteen observers.

A large section deals with recording data and reducing it to standard report forms. Another section covers meteor photography. Here I got a surprise when I calculated which of my lenses is most efficient for catching the average meteor. (The formula you use is F/f^2 , where F is the focal length and f is the f /ratio.)

The most efficient lens, by a factor of 3.5, wasn't the 28mm $f/2.8$ wide-angle, as I had been assuming all these years, but rather the 50mm $f/2$ normal one. Despite its smaller field of view, the $f/2$ focal ratio of the normal lens more than compensates for the wider field of a 28mm (at $f/2.8$) and will pick up more meteors. That was news to me: I'm going to have to try it out soon, with two 50mm's shooting adjoining fields centered about 60° off the radiant.

The last main section in the book concerns radio meteor studies. Although Levy and Edberg include a short description of it, this is a field well beyond the low-tech approach featured in the rest of the book. Wisely, they simply mention it and pass on to other matters.

Four appendices round out the book. The first discusses how to use meteor studies in a classroom to teach astronomy awareness. It tells how to tailor programs for students 8 to 12 years old and older. The second and third appendices provide a detailed list of meteor streams (about sixty in all) and a fifty-item bibliography. The last appendix contains sample report forms and instructions for visual, telescopic, and photographic meteor observations.

My only criticism is that Levy and Edberg don't describe the "zenithal hourly rate," the standard way of comparing the strength of meteor showers, or tell how one derives this artificial average from solo or group observations.

But quibbles aside, this is a very good book on meteor observing — one that every backyard astronomy library ought to have. It offers much practical advice, earned on many a long cold night, and its enthusiasm is infectious.

Catch you at the Orionids!

Robert Burnham.

Extraterrestrials

Howard Regis, Jr., ed.
278 pages, cloth, no price given
Cambridge University (1985)

This book's preface begins: "Are extraterrestrials imaginary creatures, the otherworldly equivalent of ghosts,

demons, or the Loch Ness Monster? Or are they really and truly out there, real things in the real world even as you and I?" It then investigates, in a series of papers, the likelihood of extraterrestrial life and the chances it has visited Earth.

Included are: "The Probability of Extraterrestrial Intelligent Life" by Ernst Mayr; "Is Rape Wrong on Andromeda? An Introduction to Extraterrestrial Evolution, Science, and Morality" by Micheal Ruse; "Searching for Extraterrestrials" by Jill Tarter; and "Martians and Morals: How to Treat an Alien" by Jan Narveson.

The Mars One Crew Manual

Kerry Mark Joels
160 pages, paperback, \$12.95
Ballantine Del Ray (1985)

This is, first of all, a beautiful book. Page after page of two-color diagrams, charts, and spectacular paintings (albeit black-and-white) demonstrate in exciting detail an entire imaginary human mission to Mars. The color centerfold, a painting of an astronaut exploring the proposed Candor Chasma landing site, is alone worth the price of the book. And it is an easy read, successfully treading the narrow line between the technical style of a crew manual and an accessible and even humorous style (the crew returns to a "shredded computer paper parade").

It is only on closer reading of the text that major inconsistencies appear. The book opens with a fictional history leading up to the Mars mission: an agreement between the Europeans and Soviets, which the United States later joins for obvious political reasons. Although this scenario is eminently believable, it essentially disappears from the remainder of the plot. The Americans end up running most of this "international" mission. Although this may reflect a typically American attitude, I can't imagine the other partners sitting still for it in reality.

Even more inconceivable is the date proposed for the mission: 1996. Even with a crash program, such a manned mission to Mars couldn't possibly be organized in such a short time. Worse yet, Joels suggests the development of both a lunar base and space tug (as well as the obligatory Space Station) in the same time period — clearly a political, financial, and technological improbability.

The interplanetary spacecraft that Joels proposes, which forms the real core of the book, seems in many ways much more realistic. But it too has problems. Four Space Station-derived modules are mounted in pairs on either side of a docking tunnel, becoming two habitation modules, a laboratory module, and a storage module. Mounted on this assembly is a cone-shaped Mars Excursion Module lander. A three-tank first stage powered by two uprated Space Shuttle main engines launches the spacecraft from

low Earth orbit toward Mars, and a second stage powered by a single uprated SSME executes mid-course maneuvers, slows the spacecraft into Mars orbit, boosts it back toward Earth, and finally slows it into Earth orbit. A second, aerobraked spacecraft delivers a Mars rover that will be used to travel far from the lander. It is not clear why the rover was not sent with the main spacecraft, however.

The problems of interplanetary and galactic radiation and life support — probably the greatest outstanding problems remaining to be solved before human interplanetary spaceflight becomes practical — are both inadequately covered. And the spacecraft is described as non-rotating, with the crew living in zero-g for the entire three-year duration of the mission. Recent Soviet experience appears to show that such long-term free-fall endurance is medically impractical and some sort of artificial gravity would be needed for such a journey.

Other chapters describe, in intimate detail, living and working in space, "your" activities as an astronaut both on Mars and in transit, and maintenance of "your" spacecraft.

Probably the best chapter is "Mars Science Reference," which provides a marvelously concise summary of current knowledge on the planet. The worst chapter proposes a Venus flyby on the way to Mars. Venus is described as being "like Mars" in having a thick atmosphere formed mostly of carbon dioxide, which is at best misleading. The automated probes dropped by the main spacecraft during the flyby are simply reproductions of the Pioneer Venus probes launched in 1978. The same is true of other equipment. The sources behind the technology responsible for this equipment should have been credited.

The Soviet's Venera program is described as being "somewhat successful in sending back a few precious photographs from the planet by way of unmanned 'landers.'" This unnecessarily denigrates the tremendous scientific and technological successes of a program that is in many ways as impressive as anything the United States has accomplished in space.

However, the greatest problem with *The Mars One Crew Manual* is the mission itself. It would place two astronauts on Mars at enormous expense for less than a month! Joels completely ignores most modern thinking, which at the very least envisions sending a number of scientists for a substantial period of time or, preferably, laying the groundwork for a permanent base from the very beginning. Such alternatives should have been mentioned.

The Mars One Crew Manual does demonstrate an impressive amount of research, and its vast detail can be informative. But the result is in many ways unfortunate: it is just accurate enough to

sound authoritative, yet it is not a realistic recipe for cost-effective exploration of Mars. Read this one with a very large grain of salt. *Donald F. Robertson.*

Black Holes: An Annotated Bibliography, 1975-1983

Steven I. Danko
282 pages, cloth, \$25
Scarecrow Press (1985)

Some 1,882 entries of reference books, popular articles, technical articles, and newspaper articles about black holes published from 1975 to 1983 are included in this book.

From Black Cloud to Black Holes

Jayant V. Narlikar
147 pages, paper, \$14
World Scientific (1985)

This thin volume provides a brief glimpse at the processes governing star birth and death and contains information on stellar distances, masses, and behavior according to spectral type.

Space Garbage

Jack Meadows
160 pages, cloth, \$17.95
George Philip (1985)

Space Garbage is a book about comets, asteroids, meteors, and other debris inhabiting the solar system. After describing their composition, the author then speculates on the collisions these bodies have had with Earth and other planets.

Nucleosynthesis

W. David Arnett and
James W. Truran, eds.
308 pages, paper, \$18
University of Chicago (1985)

Nucleosynthesis, subtitled "Challenges and New Developments," is the proceedings volume from a conference held at Yerkes Observatory in 1983.

Recent Advances In Planetary Meteorology

Garry E. Hunt, ed.
161 pages, hardcover, \$39.50
Cambridge University Press (1985)

Comprised of invited papers written by various planetary scientists for the Commission on Planetary Atmospheres and Their Evolution, this book examines the physical and dynamical processes governing planetary meteorology on all the planets except Neptune and Pluto. Articles include "Photochemistry and Clouds of Jupiter, Saturn, and Uranus," "Martian Local Dust Storms," and "The Meteorology of Jupiter and Saturn."

Interacting Binaries

P.P. Eggleton and J.E. Pringle, eds.
410 pages, cloth, no price given
Reidel (1985)

These are the proceedings from a NATO Advanced Study Institute on Interacting Binaries held at Cambridge, England, in 1983. Among the papers are: "Observational Evidence for the Evolution of Contact Binary Stars" by S.W. Mochnacki; "Massive X-Ray Binaries" by N.E. White; and "Stars that go Hump in the Night: The SU UMa Stars" by B. Warner.

Progress in Stellar Spectral Line Formation Theory

John E. Beckman and Lucio Crivellari, eds.
448 pages, cloth, \$59
Reidel (1985)

A proceedings volume from the NATO Advanced Research Workshop in Progress in Stellar Spectral Line Formation Theory held at Trieste, Italy, in 1984.

Dynamics of Star Clusters

Jeremy Goodman and Piet Hut, eds.
622 pages, cloth, \$69
Reidel (1985)

This proceedings volume features material from the 113th symposium of the International Astronomical Union held in Princeton, New Jersey, in 1984. Among the many papers are: "A Deep Luminosity Function for 47 Tucanae" by William E. Harris and James E. Hesser; "Space Telescope Observations of Globular Clusters" by John H. Bahcall; "Structure Parameters of Globular Clusters" by Ronald F. Webbink; and "On the Dynamics of Open Clusters" by V.A. Ambartsumian.

Electronics Oriented Astronomy

John Sanford, ed.
47 pages, paperback, no price given
Orange County Astronomers Publications (1986)

These are the proceedings of the second seminar on electronics-oriented astronomy held by the Orange County Astronomers. The book includes articles about image processing in amateur astronomy and how it can be done on an IBM PC, image intensifiers, and photoelectric photometry.

The A.L.P.O. Solar System Ephemeris: 1986

John E. Westfall, ed.
102 pages, paperback, \$5
Association of Lunar and Planetary Observers (1985)

This is the first annual edition of the Association of Lunar and Planetary

Observers solar system ephemeris and is intended to be a convenient single reference for the data needed by observers of solar system objects.

Radiotelescopes, 2nd Edition

W.N. Christiansen and J.A. Hogbom
265 pages, cloth, \$59.50
Cambridge University Press (1985)

This book details radio telescope design and operation for graduate students and research workers.

Interdisciplinary Approaches to Astronomy

Astronomical Society of the Pacific
32 pages, paper, \$3
Astronomical Society of the Pacific (1985)

This booklet consists of reprints of several articles from the Society's nontechnical magazine, *Mercury*. They concern the relationship of astronomy to the humanities, particularly music, science fiction, and poetry.

Seven Clues to the Origin of Life

A.G. Cairns-Smith
131 pages, cloth, \$17.95
Cambridge University Press (1985)

Written in the style of a detective novel, this is a nontechnical look into the questions surrounding the origin of life.

Meteorites

John T. Wasson
267 pages, cloth, no price given
W.H. Freeman (1985)

As the subtitle, "Their Record of Early Solar-System History," implies, this book discusses the solar system's formation and early evolution by using meteorites as tools. After discussing the various types of meteorites, their composition, ages, and other characteristics, the author explores their value as remnants of the early solar system in developing and constraining models of that history.

Accretion Power in Astrophysics

J. Frank, A.R. King, and D.J. Raine
273 pages, hardcover, \$59.50
Cambridge University Press (1985)

According to this book's introduction, in the nineteenth century "gravity was the only conceivable source of energy in celestial bodies, but gravity was inadequate to power the Sun for its known lifetime"; while today "it is to gravity that we look to power the most luminous objects in the universe, for which the nuclear sources of the stars are wholly inadequate."

This book discusses astrophysical

accretion in those objects where it is suspected of contributing a significant fraction of the total radiation. Intended for graduate students and advanced undergraduates with a physics background, special attention is given to close binaries containing a compact object and to active galactic nuclei and quasars.

High Resolution in Solar Physics

R. Mueller, ed.
317 pages, paper, \$20
Springer-Verlag (1985)

This work covers instrumentation and techniques of solar observations as well as theoretical interpretations of various small-scale solar features.

The Case for Mars II

Christopher P. McKay, ed.
716 pages, cloth, \$60; paper, \$40
American Astronautical Society (1985)

During the summer of 1984, the Case for Mars II conference was held at the University of Colorado in Boulder. It brought together an expanded group of people and resulted in this volume of proceedings.

The book is divided into sections covering many aspects of the exploration

of Mars: national and international considerations, necessary or desirable precursor missions, science programs, transportation systems to Mars, technology needed for surface exploration, and utilization of Martian resources. Although some of the papers are of a technical nature, large portions of the book are accessible to a general readership.

A Brief History of the Cincinnati Astronomical Society

John E. Ventre and Edward J. Goodman
131 pages, paperback, no price given
Cincinnati Astronomical Society (1985)

On the occasion of its seventy-fifth anniversary, the Cincinnati Astronomical Society has printed this history covering the period from its origin in 1841 to the present.

Origins

Robert Shapiro
332 pages, cloth, \$17.95
Summit Books (1985)

Subtitled "A Skeptic's Guide to the Creation of Life on Earth," this book investigates the possibility that traditional scientific theories about the origin of life may be considerably wrong.

Astronomy and Astrophysics Abstracts, Vol. 39

S. Bohme, et al., eds.
1149 pages, cloth, \$79
Springer-Verlag (1985)

Astronomy and Astrophysics Abstracts indexes and briefly explains 11,582 articles published in many astronomical periodicals during the first six months of 1985.

Long-Term Evolution of Short-Period Comets

A. Carusi, et al.
Loose-leaf sheets and notebook, \$85
Adam Hilger (1985)

A four-ring binder filled with accounts of the long-term behavior of many comets' orbits. The authors intend to update this work with new information once every three years.

My First Book of Space

Rosanna Hansen and Robert A. Bell
20 pages, hardcover, \$7.95
Simon & Schuster, Inc. (1985)

This is a young person's introduction to the solar system and the stars. NASA photographs are featured.



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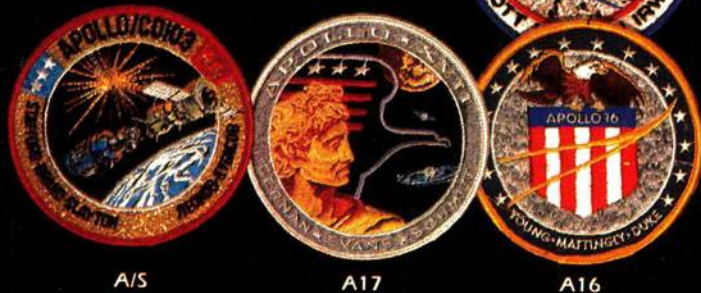
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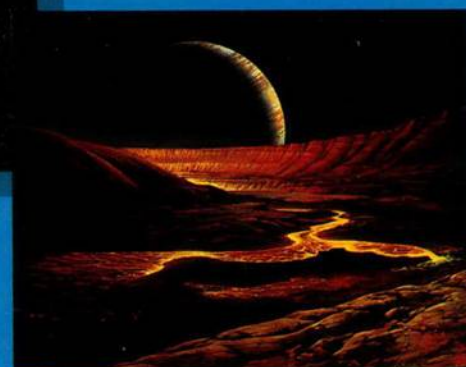
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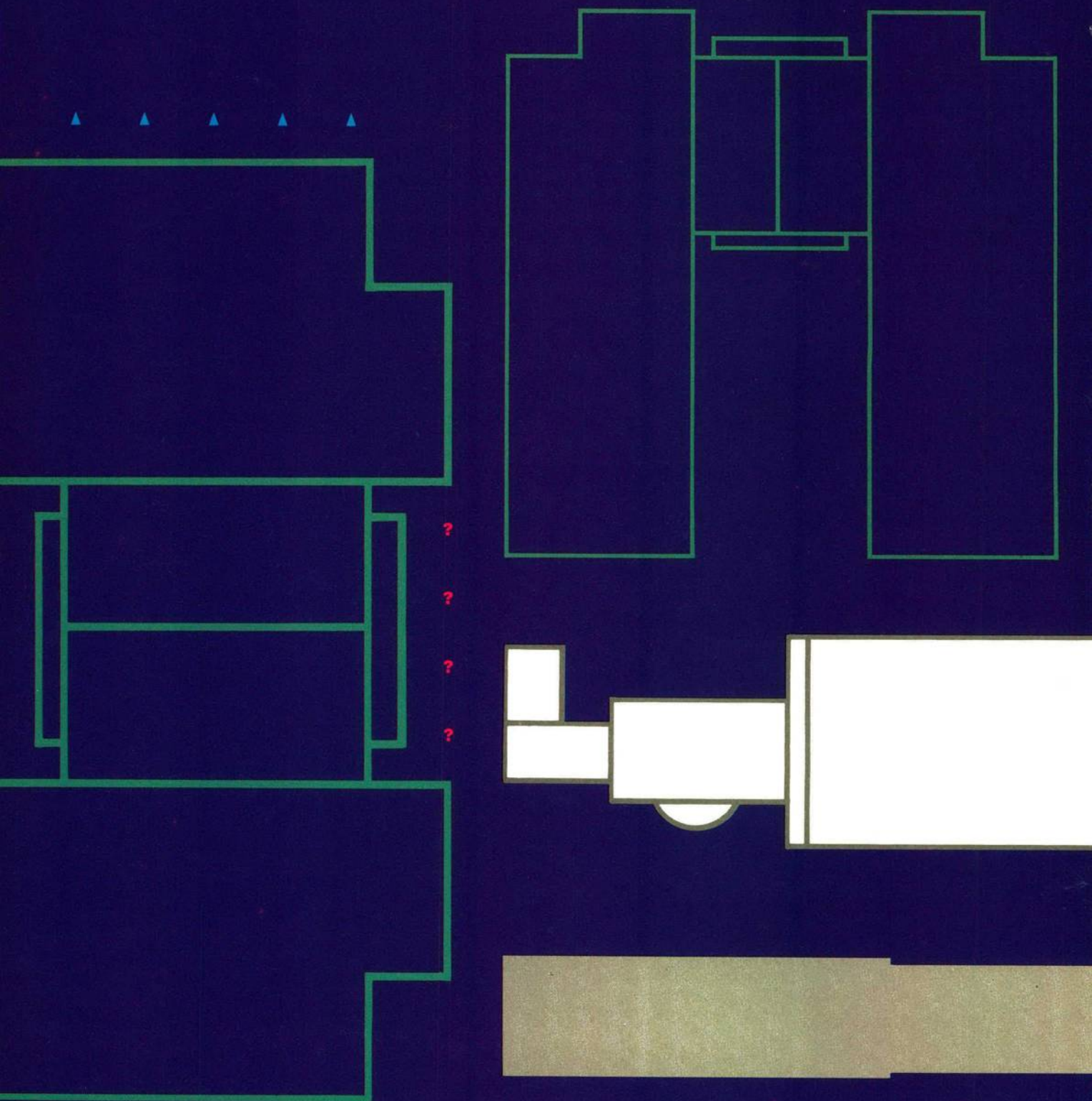
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The 1986 ASTRONOMY Guide To Telescopes



Ring! Ring!

"Hello. . . . Yes it is. . . . You'd like to buy a telescope? . . . I see. Have you looked at the ads in ASTRONOMY? . . . You did? . . . Well, we never said picking the right telescope would be easy, you know."

There are so many telescope sizes, models, features, and accessories on the market that it might seem tempting at times to forget the whole thing and go buy a stereo, VCR, or sailboat instead. But — hold on — if too much choice is getting you down, we're here to guide you through the process of choosing a telescope that's right for you.

Where should you begin? Oddly enough, the place to start is with you. You see, it's your interest in astronomy, not the telescope itself, that determines the best telescope. What makes deciding on a telescope so difficult is that you have to figure out what you'd like to see and do in astronomy — planets, double stars, deep-sky objects, astrophotography, or just a little bit of everything — before you've seen it or done it. Once you have an idea of what each of the many types of telescopes can do you'll be able to judge which one is for you.

One important thing to remember about telescopes — something so obvious it's easy to forget — is that whatever telescope you get, you'll be looking at the same sky. Of course some telescopes are better for seeing some things than others, and that's what we'll be talking about. Basically, though, you can get off to a pretty good start in astronomy with any reasonably good scope. (Well, maybe not that scope your cousin bought in a rummage sale.)

Binoculars

"Binoculars. . . . No, we're not kidding. They're great for getting started in astronomy. . . . You already have a pair. . . . Well, so much the better."

And we're not kidding.

Binoculars are really two telescopes side by side — a telescope for each eye. While binoculars can't do everything a telescope can do, a good pair of binoculars is an excellent introductory "telescope" for the whole field of astronomy. Binoculars are easy to use, versatile, portable, and the whole family can enjoy them for sports, hunting, or birdwatching. Another plus is that you may already own a pair.

But not all binoculars are equally suitable for astronomy. There's an easy way to find out whether the binoculars you have, or ones you plan to buy, are suitable. Somewhere on the instrument, usually just below the brand name of the manufacturer, you'll find some numbers — 8x20 or 7x35, for example. The first number is the magnification and the second number is the diameter of the front lenses in millimeters. Divide the diameter by the magnification and you'll get a number called the "exit pupil." This is the diameter of the bundle of light rays that

comes out the binocular eyelens.

If the exit pupil is 5 millimeters or larger, the binocular is excellent for astronomy. If it is smaller than 4 millimeters, the instrument is intended primarily for daytime use. 8x20 binoculars, for example, have an exit pupil of 2.5, which is too small for serious star watching. 7x35 binoculars have a 5-millimeter exit pupil and would be satisfactory.

The most commonly recommended, all-around binoculars for astronomy are 7x50s. During World War II, 7x50s were called "night glasses." The exit pupil is 7 millimeters, the same size as the pupil in your eye. You'll get a bright image and a wide field of view that's well suited to scanning large regions of sky and viewing large objects, like comet tails or diffuse nebulae. Well-made 7x50 and 10x50 binoculars are larger and heavier than most ordinary binoculars, but for the money you can't beat them for stargazing.

Evaluating binoculars is fairly easy. Pick it up, grasp the tubes firmly, and try to wiggle them. There should be no looseness or play. Check that the eyepieces are solidly mounted (with the "wiggle test") and that they move smoothly when you turn the focus knob. Look through them, either across the store or down the street. Are the images crisp and bright or do you see mushy images and funny-colored fringes around bright objects? After you've tried half a dozen pairs — some good and some not so good — you'll be able to spot the differences easily.

When you shop for binoculars, shop for quality rather than price. Of course you'll find cheap units on the market, but inspect them carefully and look at what you don't get. You probably won't find the quality you'd really like for under \$100. Look for both optical and mechanical quality before making a decision.

Many amateur astronomers who own a telescope already own binoculars. Although ordinary binoculars do not have enough magnification or light grasp for seeing the subtle details in nebulae or star clusters, they're portable, light, relatively inexpensive, and offer the viewer bright images and ease in finding faint celestial objects.

There are so many brand names in binoculars that it's hard to know where to start. Many of the famous name-brand camera manufacturers sell them: Leitz, Nikon, Pentax, and Minolta. Bausch and Lomb, Fujinon, Swift, Steiner, Celestron, and Swarovski are also recognized names in the field. Camera dealers, telescope dealers, and sporting goods stores often carry one or more brands.

Big Binoculars

"Of course they cost more, but you see more with them, too. . . . Yes, you'd need a tripod to support them properly."

For serious astronomers, there's a second binocular option — big binoculars. With lens diameters greater than 60mm

and a magnification of a least 9x, big binoculars reveal fainter stars and nebulae than ordinary binoculars and still offer the comfort of two-eye viewing and portability. You'll find big binoculars sporting specs of 9x63, 10x60, 11x70, and 12x80.

At appropriately high prices, you can even buy giant binoculars — 16x100s and even incredible 25x150s by Fujinon. However, the most practical ones for casual astronomy are the smaller, lower-power sizes. Some 70mm and 80mm binoculars feature magnifications of 20, 25, and even 30 times. To determine their suitability for astronomy, divide the aperture by the magnification to find the exit pupil, just as you did for ordinary binoculars. If the exit pupil is smaller than 4 millimeters, then it's not optimum for astronomy.

For looking at large nebulae or scanning the Milky Way, big binoculars are tops. Even if you already have a medium or large-size telescope but realize that it is too bulky or too heavy to take on a camping trip to a dark-sky site, you'll find big binoculars are your best bet. But because of their weight and magnification, you'd better plan on buying a sturdy tripod, too.

In the astronomical field, scores of telescope dealers carry the Celestron, Star Flite, H.T. Builderus, Fujinon, and Meade brands of big binoculars, and a variety of other imports are available at camera dealers and telescope stores.

Spotting Scopes

"You're thinking of a spotting scope? . . . Well, to be honest, they're usually just barely adequate. . . . A camera tripod is okay for casual stargazing but isn't a good enough mount for real astronomy."

Spotting scopes are the next step up from binoculars. They are telescopes that give an upright image (astronomical telescopes often invert the image) and are sold mainly for looking at, or spotting, wildlife, movie stars, auto races, and birds, or for use in sports and target shooting. Two types are common on the market today: lens-type spotting scopes and mirror-lens (catadioptric) spotting scopes. The mirror-lenses tend to be larger and more powerful.

Typically, spotting scopes have a lens diameter, or aperture, between 60mm (typical of lens-type scopes) and 100mm (typical of mirror-lens types) with magnifications between 15x and 60x. Most of them have too high a magnification to use without a tripod. If you try to hand-hold the scope, the shaking of your arms will make seeing anything virtually impossible. If you don't already have a sturdy tripod, plan on ordering one with the spotting scope.

If you've studied the ads, you've probably noticed that spotting scopes are a lot less expensive than astronomical telescopes with the same specs. The big question on your mind is, "What do I get

for spending about twice as much for an astronomical telescope?" The answer is that you get an adequate mount. Although a good spotting scope on a camera tripod might do if you feel like sampling a little astronomy, it probably won't have the capability you'll need for exploring the whole field of astronomy seriously.

What should you look for in a spotting scope? You'll need ample aperture if you hope to do much astronomical observing. Spotting scopes with 30mm or 40mm lenses won't give the large, bright views you want. Once again, divide the aperture by the magnification to find the exit pupil. With zoom spotters or those with more than one eyepiece, use the lowest magnification. The exit pupil should turn out to be 5 millimeters or larger for best results.

Check also for solid construction. Do things inside rattle when you shake it? Do the eyepieces fit securely? Is the tripod socket heavy duty? Having a look at a few top-of-the-line spotting scopes is a big help. Even if they cost more than you want to spend, check out a few well-made instruments, then try to find the same solidity in your price range.

As is the case with binoculars, there are dozens of spotting scope makers and thousands of retailers. Typical lens-type spotting scopes are produced by Bausch and Lomb, Bushnell, and Swift. Celestron, Meade, and Bushnell make the most widely marketed catadioptric spotting telescopes. You'll find them in camera stores, telescope stores, and sporting goods and hunting stores.

Small Refracting Telescopes

"You say you like the looks of a refractor? ... Sure. ... Is this your first scope? ... Their performance? Not bad. What are you interested in observing? ... Everything? Well, small refractors are good all-around first scopes. ... No. For observing galaxies you'd need more aperture."

With apertures between 50mm and 80mm, tube lengths between two and four feet, mounted equatorially or alt-azimuth style, small refractors are excellent first telescopes. The classic instrument is the 60mm (2.4-inch) refractor, a telescope large enough to show lunar craters, Jupiter's satellites and cloud bands, the rings of Saturn, the polar caps of Mars, lots of double stars, and even a few hundred star clusters and nebulae.

Refractors have been with us since Galileo, but Galileo's telescopes were not very good. They consisted of a single lens made from one type of glass, and they suffered from severe "chromatic aberration," which means the lens couldn't bring all the colors of light to focus at once. Achromatic lenses, perfected around the time of the American Revolution, consist of two lenses made of different types of glass. By nearly eliminating chromatic aberration, the performance of small achromatic lenses

approaches optical perfection.

As recently as five years ago, small refractors had become almost extinct. Most of them were oriental imports. International monetary fluctuations drove their prices so high relative to Newtonian telescopes (see section below) that small refractors were no longer a good choice for a first telescope. Curiously, they came back as currencies shifted and lowered the cost of import optics, and as the prices of domestic Newtonians and catadioptric telescopes rose. But something else has happened, too. The best modern imports are well-made, reliable instruments that offer real value to the beginner.

Unlike spotting scopes, which they otherwise resemble, small astronomical refractors come with mounts that allow you to point them toward the celestial object you want to view. Furthermore, you can switch from one eyepiece to another for different magnifications. This allows you to observe, for example, the entire disk of the Moon at 40x magnification, the sunlit limb at 80x, and finally zero in on a few craters at 150x. Quality brand names include Unitron, Pentax, Celestron, Meade, Parks, and Swift.

Small Catadioptric Telescopes

"Cat is short for catadioptric — CAT-uh-die-OP-trik. ... It means the scope has both lenses and mirrors in it. ... Right, the ones with the stubby tubes. ... Yes. Orange, blue, or black."

Catadioptrics are hybrids. They have both mirrors and lenses in the optical train. Because the light path is folded inside the telescope, they're compact and very, very portable. Small catadioptric telescopes are those with apertures between 85mm (3½ inches) and 125mm (5 inches) and tubes only about a foot long.

Many of the spotting telescopes we discussed earlier also have catadioptric optical systems. In fact, catadioptric spotting scopes and astronomical catadioptrics of the same make usually have the same optical system. What is it that sets the astronomical catadioptrics apart from spotting scopes? Simply this: the telescope is attached to a mount that is designed to track the stars. With a built-in drive gear, the mount slowly swings the telescope around to follow the stars.

In addition, astronomical telescopes come with two or more eyepieces so that you can easily find celestial objects at low magnification then examine them closely at high magnification. Many spotting scopes include only one eyepiece. Astronomical catadioptric telescopes usually include a finder telescope for locating faint sky objects; many spotting scopes do not.

There are several types of catadioptrics. Some have Schmidt-Cassegrain optical systems (with a thin, almost flat corrector lens), while others have Maksutov-Cassegrain optics (with deeply-curved corrector lenses). Both types are catadioptrics and both are capable of excellent

optical performance. The corrector lens (either Schmidt or Maksutov style) is placed at the front of the telescope tube, the primary mirror is at the back end of the tube, and a small secondary mirror is mounted on the corrector lens. The light goes through a hole in the primary mirror and comes out the back of the tube. The light path in the telescope is folded, so a long focal length can fit into a short tube.

Outstanding small catadioptrics include the Questar 3½, an 89mm f/14.4 Maksutov system on a two-arm fork-style mount, featuring unusually fine workmanship and design throughout; the Celestron C90, a 90mm f/10 Maksutov on a one-arm fork mount that is very short and portable; the Meade 2040, a 102mm f/10 Schmidt-Cassegrain with a handsome dark blue finish on a one-arm fork mount; the Bushnell Criterion 4000, a 102mm f/10 Schmidt-Cassegrain on a two-arm fork mount, readily convertible to a telephoto lens; and the JSO-12B, a rugged 120mm f/10 Schmidt-Cassegrain with optional German equatorial mount.

Small Newtonian Telescopes

"Best buy? Probably a Newtonian. ... Right, there's a concave mirror at the bottom end of the tube. ... You look in near the top of the tube. ... Yes, they need a little more care and attention than other kinds of scopes."

In terms of optical performance per dollar invested, no telescope rates better than a Newtonian. Invented by the great English physicist Sir Isaac Newton, the Newtonian's optical system consists of a precision mirror at the lower end of the tube and a small mirror near the top to direct the image out the side, where you view it. To provide the highest performance at the lowest cost, small Newtonians have spherical mirrors and relatively long focal lengths. This means that Newtonian telescopes tend to be longer than equivalent catadioptrics because the light path is not folded back on itself.

Mounted atop a sturdy tripod with a solid equatorial mounting, a small Newtonian is an excellent first telescope for astronomy. The Newtonian optical system is much simpler than achromatic lens or catadioptric optical systems, and therefore is much less expensive than refractors or Schmidt-Cassegrains of the same aperture. However, only a few manufacturers make Newtonians in the beginner's range, those with apertures around 4 inches. One important telescope option is to build a small- or medium-aperture Newtonian (see section below).

In the retail market, Jason/Empire and Tasco offer inexpensive imported Newtonians through a variety of nationwide chains and discount outlets. Unfortunately, these stores seldom have knowledgeable sales personnel to demonstrate the equipment or help you in making a sound purchasing decision.

Small Newtonians can even be pretty

classy. Edmund Scientific's unique ball-mounted 102mm f/4.5 Newtonian, the Astroscan 2001, features a cast-plastic tube with a ball on the end. The ball turns in a simple tripod casting. The resulting telescope is compact, inexpensive, easy to use, and offers bright, clear images and wide-field viewing. For deep-sky observing while camping or hiking, the Astroscan combines the ease of use and low magnification of big binoculars with the light-gathering power and resolution of a quality telescope.

Astronomical Refractors

"Oh yes, refractors are becoming more popular. . . . Sure, they're relatively expensive. . . . Why? It's their optical performance. . . . Planetary and lunar observing, most obviously, but also deep-sky."

The sheer pleasure of razor-sharp images on a velvet-black field qualifies the refractor — especially the superb apochromatic refractors now on the market — as tops in high-fidelity viewing. Serious refractors are largely confined to the 4-inch to 8-inch aperture range, and generally deliver better images of the planets, the Moon, double stars, star clusters, and comets than somewhat larger catadioptrics or Newtonians.

The reasons for this are three: it is easier to produce a precise optical surface on a lens than on a mirror; the optical system is unobstructed; and the tube is closed, which reduces image-disturbing internal temperature variations. Furthermore, it is easier to stop stray light from "fogging" the image produced by a refractor.

There are currently three types of astronomical refractor lenses: the classic achromatic doublet, the fluorite doublet, and the apochromatic triplet. The terminology is slightly confusing, since the words achromatic and apochromatic look a lot alike. The "a-" prefix means the lens is "without" color; "apo-", on the other hand, means "totally free of."

Classic achromatic refractors have served astronomy for over 200 years. An achromat has lenses made from two different types of glass (hence the term doublet) to partially correct chromatic aberration, but even the best achromats are limited by the physical properties of glass. To reduce troublesome color fringing, focal lengths are kept long. For a 4-inch lens, the focal length should be at least 40 inches; for a 6-inch lens, 90 inches; for an 8-inch lens, 160 inches. Conventional achromatic refractors built to these limits perform superbly. Shorter focal lengths offer greater convenience and portability, but there is no escaping chromatic effects.

Among the makers and importers of 4-inch achromatic refractors are TeleVue, noted for the handsome brass 4-inch f/5.5 Renaissance refractor (which can double as a super-precision telephoto lens for medium-format cameras); the Cheshire

Instrument Company, makers of a compact 5-inch f/5; and Unitron, Meade, Celestron, Pentax, Edmund, and Parks, marketing conventional long-focus (i.e., between f/10 and f/15) instruments in a variety of apertures. Vernorscope sells a highly corrected 80mm system.

The Jaegers Optical Company supplies precision refractor lenses in a variety of sizes up to a 6-inch aperture and in focal ratios of f/5, f/8, f/10, and f/15. Their lenses enjoy a fine reputation. Dobbins Instrument Company, Goto Optical Company, and Carl Zeiss make precision refractors of 6-inch and larger aperture.

Among the doublet, or two-lens, refractors, however, there is an exception. Lenses using a very expensive optical material called calcium fluorite have far less residual chromatic aberration than ordinary achromats. Lenses made with fluorite show virtually none of the purple halo of secondary spectrum so characteristic of classic doublets, and because a long focal length is not necessary to control color, these refractors are usually considerably shorter than comparable achromats. Because fluorite is so expensive, fluorite refractors seldom exceed 4 inches in aperture. Leading fluorite refractor brands include Takahashi and Celestron.

Finally, there are the apochromatic triplets, or three-lens designs. These use three different types of glass, rather than the two types used in achromats. Like fluorite lenses, triplet refractors offer almost complete freedom from color but in larger apertures and at lower prices than fluorite lenses. Apochromats are fully color-corrected at relatively short focal lengths. A 6-inch apochromatic triplet can easily have better color correction at f/8 than a doublet does at f/15. The only maker of apochromatic triplets is Astro-Physics Corp. with a quality line of 4-inch, 5-inch, and 6-inch apochromats and photo-apochromatic telescopes.

Astronomical Catadioptrics

"They certainly do offer a lot for the money. . . . Which is the best? It's hard to say. . . . Each has its pluses and minuses. . . . You'll just have to test them and decide for yourself."

Catadioptrics are, without a doubt, the most popular type of telescope made today. By packaging a large aperture (8 inches) in a short tube, the Schmidt-Cassegrain telescope, or SCT, utterly revolutionized amateur astronomy a little over a decade ago.

Why is this? An 8-inch Schmidt-Cassegrain telescope doesn't offer superior resolution or better light grasp than any other 8-inch telescope; in fact, the relatively large central obstruction actually makes them slightly worse than Newtonians and refracting telescopes of the same aperture. What makes the difference is their portability, compactness, and convenience. In a time of growing light

pollution and smaller houses and cars, the SCT offers many telescope buyers just what they need.

Originally introduced by Celestron International, the marketplace now supports three domestic manufacturers: Celestron, Meade, and Bushnell. Furthermore, to the benefit of the consumer, intense brand-name competition works to keep prices low and quality high in these versatile instruments. All three makers offer 8-inch f/10 fork-mounted Schmidt-Cassegrain catadioptrics.

The SCT optical system consists of a primary mirror, a thin correcting plate, and a secondary mirror mounted on the inside of the corrector plate. By folding the optical path inside the telescope, the system packs an f/10 focal ratio into a tube length only twice the diameter of the primary mirror. These instruments are focused by moving the primary mirror, so attaching cameras or other apparatus is greatly simplified.

Full accessory lines — eyepieces, star diagonals, solar filters, and the like — are offered for all three brands, and third-party makers sell everything from sophisticated cameras for astrophotography (Lumicon) to photoelectric photometers (Optec and Thorn-EMI-Gencom) for the Celestron, Meade, and Bushnell SCTs.

Until a few years ago, all SCTs were fork mounted. The fork attaches to a drive base with an internal gear for tracking. The base attaches to a latitude wedge, and that, in turn, bolts to a heavy-duty tripod or pier. The optical tube assembly, fork, and drive base are usually sold at a base price, with the latitude wedge and tripod sold separately. Without these vital "optional" accessories, however, these telescopes are difficult to use for astronomy.

Celestron and Meade now offer an alternate mount: a light, computer-controlled German equatorial mounting (Meade calls this mount the "GEM") with optional computer control that automatically moves the telescope from one celestial object to another. Celestron has recently introduced a heavy duty, computer-controlled mounting that can automatically locate any of the thousands of stars and deep-sky objects stored in its memory.

Celestron's SCT line includes the 8-inch aperture Super C8 and Super C8+, both f/10; the 11-inch f/10 C11; and the massive 14-inch f/11 C14. These instruments include two-arm fork mounts with precision worm-gear drive systems. Meade's line includes the 8-inch f/10 model 2080/LX3 with built-in quartz electronic drive corrector and the 10-inch f/10 model 2120/LX3. A two-axis drive-corrector is a standard option on these units. Bushnell's line includes the Criterion 6000, a 6-inch f/10 SCT, and the 8-inch f/10 Criterion 8000 SCT.

Catadioptrics include both SCTs and Maksutov-Cassegrains. One major manufacturer, Questar, offers high-quality

Maksutov-Cassegrain telescopes. With apertures of 7 and 12 inches, the Questar 7 and Questar 12 have long been the "dream machines" of amateur astronomy — beautifully machined precision instruments featuring superb optics. The Questar 7 comes with a compact fork mounting, and the Questar 12 is available on a massive German equatorial.

For the serious astrophotographer, the 12-inch f/5 AstroMak is the ultimate astrocamera. It features the wide-angle, flat-field Simmons-Maksutov (Simak) optical system. Designed with astrophotography in mind and exquisitely engineered, the AstroMak is capable of covering a 3° field of view with photographically perfect images. Although the price is high, the AstroMak's images rival those produced by the giant Schmidt cameras at professional observatories.

Newtonian Reflectors

"Newtonians are named after Sir Isaac Newton. . . . Yes, he invented the reflector. . . . It's got a mirror rather than a lens. . . . The selling point is usually aperture."

When they need lots of light-gathering power for observing faint nebulae and galaxies, most observers immediately think of Newtonian reflectors. This, however, sells the Newtonian design short. Newtonians have long been used for high resolution planetary observing, and they also deliver impressive astrophotographic capabilities at relatively low prices.

Nowadays there are two types of Newtonians: the classic equatorially mounted Newtonian and the so-called Dobsonian telescope, which is actually a Newtonian on a special alt-azimuth mounting. (We cover Dobsonians in a section below.) For low-magnification deep-sky observing, the alt-azimuth Dobsonian is outstanding. If you want a clock drive so your telescope can follow the stars, be sure to get a reflector with an equatorial mount.

Newtonian telescopes are big in capability, but they're also just plain big. The elegantly simple two-mirror optical system requires that the tube be as long as the focal length of the telescope, so a 12-inch f/8 Newtonian is nearly 8 feet long! Equatorial mounts capable of supporting such large telescopes must be exceedingly solid and are usually quite massive. Obviously climbing up to look into the eyepiece could be a problem, too. Large Newtonians come with tube rotating rings to allow turning the eyepiece to a comfortable observing position. Despite these apparent drawbacks, Newtonians work very well as backyard telescopes, especially when the owner can store them in a nearby garage or shed, or cover them with a roll-off shelter. Six- and 8-inch Newtonians are generally light enough to carry outside easily and portable enough to put in a car.

The principal brand names in equatorially mounted Newtonian telescopes are Parks, Meade, and Celestron. Parks' Newtonians come in 6-, 8-, 10-, and 12-inch apertures on your choice of medium- or heavy-duty equatorial mounts. Meade offers 6- and 8-inch Newtonians for the beginner, and "research grade" instruments in 8-, 10-, and 12-inch apertures. Celestron offers 6- and 8-inch aperture f/5 Newtonians.

Star Instruments sells a compact 6-inch f/4 richest-field telescope, with or without mounting, under the name "Stargazer." Meade offers two low-price Newtonians, one a 10-inch f/4.5 and the other a 16-inch f/4.5 for deep-sky observers under the "Deep Space" rubric. The Star Liner Company offers a complete line of equatorial fork-mounted Newtonians, convertible Newtonian-Cassegrains, and custom-made units up to a 24-inch aperture.

Both equatorial and Dobsonian Newtonians are well-suited for do-it-yourselfers who want to build their own telescopes. Home-builts can perform as well as the commercial instruments, and they offer the astronomer the chance to actually build a large and powerful telescope.

Dobsonian Reflectors

"That's right. They're very big. . . . Right. Nothing beats 'em for observing nebulae, star clusters, or galaxies."

The flip-side of modern Newtonians are Dobsonians. Named after John Dobson of the San Francisco Sidewalk Astronomers, the Dobsonian alt-azimuth design permits amateurs access to very large telescopes — as large as a 29-inch aperture. Although the Dobsonian mount does not automatically track the stars, the mount should move so smoothly that the observer adjusts the telescope almost without thinking about it.

Big Dobsonians offer, above all else, enormous light-gathering power. They are largely responsible for creating today's corps of deep-sky observers. (These hardcore fanatics have seen deep into space, studied first-hand the filigree structure of faint nebulae, and viewed the spirals of distant galaxies with their own eyes — and they're proud of it.) Built of cardboard tube and plywood, Dobsonian telescopes offer the greatest light-gathering power per dollar ratio in the telescope industry. They are, however, quite specialized telescopes, and those above 13-inch apertures are difficult to transport.

However, Dobsonians make good sense in small apertures, too. As a do-it-yourself telescope project, Dobsonians are mechanically simple to build and give good performance when completed.

For those who want a finished telescope, Telescopes offers 6-inch f/5 and 8-inch f/5 Newtonian reflectors in natural oak Dobsonian mountings. Coulter Optical is the major domestic maker of Dobsonian telescopes. Their Odyssey line

includes the Odyssey 8, an 8-inch f/4.5, a good low-price beginner's telescope; the Odyssey Compact, a 10-inch f/4.5; the Odyssey I, a 13.1-inch f/4.5; the Odyssey II, a 17.5-inch f/4.5, perfect for serious deep-sky observers; and the Odyssey 29, a 29-inch f/4.5 giant suitable for an entire astronomy club. Coulter also sells finished mirrors for amateur astronomers who want to build their own large-aperture Dobsonian telescopes.

Sky Designs offers both finished and do-it-yourself Dobsonian kits. These scopes knock down for transport so you can take it with you, even in a compact car.

Versatility, Size, Weight, and Price

"How wide is the back seat of your car? . . . I hope you enjoy lifting weights."

Selecting the right telescope is a personal choice. However, we can offer some broad hints that may help you decide where to concentrate your efforts. The first thing to consider is versatility: how many things can you do with the telescope? Binoculars are versatile, but they're limited. Spotting scopes are useful only for broad, general sky watching. Even the most powerful catadioptric spotter, without a mounting suitable for astronomy, is severely limited — best for sticking a toe in to test the water.

Small telescopes — 60mm refractors, 4-inch catadioptrics, 4-inch f/10 Newtonians, and the Astroscan Newtonian — offer the best of both worlds. They are ideal for beginners. Powerful enough to reveal a wealth of lunar detail, features on Mars and Jupiter, the rings of Saturn, star clusters, and some galaxies, they can also be used for some spotting, especially serious birdwatching. For a serious nature lover who'd like to find out what astronomy is all about, a small astronomical telescope is the best bet.

Astronomical telescopes are another ball game entirely — they're getting very specialized. Large Newtonian and Dobsonian telescopes triumph for observing deep-sky objects. Refractors, especially the achromats and nearly optically perfect apochromats, give great satisfaction to planetary observers. Catadioptrics offer a bit of everything, winning hands-down for astrophotography, while medium and large-size Newtonians provide the highest performance per dollar ratio and a high degree of versatility.

However, the telescope that will show you everything you want to observe may not actually be the most practical. Powerful astronomical telescopes that are the ultimate for examining the cloud belts of Jupiter or are best for seeking out thousands of faint galaxies may be twelve feet long or weigh well in excess of 500 pounds, not to mention the price! Somewhere along the line, the physical height, length, and weight of the instrument must be part of your overall assessment.

When, where, and how do you intend

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to observe? Again, don't kid yourself. A backyard telescope has to be carried out and set up each time you use it, unless you can leave it out all the time. If you live in the city and have a yen for deep-sky observing, you may have to trek with your telescope in search of dark skies. Will the telescope you're considering fit in: a) your Toyota? b) your Ford Impala? c) your new Astro van? d) a ¾-ton pickup? e) none of the above? In short, it's better to have a small telescope that you will use than a large one you won't because it's too much of a hassle.

Finally, there's the price to consider. Only you know how much money a telescope is worth to you, although your family may want to have some say in how much money you spend on it. Unlike the home computer (which you had hoped everybody in the family would use) or the VCR (which everybody does use), telescopes tend to be single-user hardware. In terms of family politics, it might make more sense to get a small telescope in hopes of gaining allies for the cause of backyard astronomy, rather than trying to convince the others to let you make a large expenditure that you alone will enjoy. Amateur astronomy is an infectious interest, but there are those who are immune to the charm of the stars.

Local Dealer vs. Buying by Mail

"Two to three weeks, but it depends on the store. . . . Delivery times have been good since the beginning of summer. . . . Right. Since Halley's been gone. . . . Absolutely. Shop around. Compare prices."

Nowadays most telescopes are boxed at the factory, passed on at wholesale prices to a network of dealers and retail outlets, and offered to the consumer — that's you — at somewhat below full list price. Depending on where you live, you may well have a choice between buying from a local telescope store or ordering from a dealer halfway across the country — at a significantly lower price.

There are a few things you ought to consider. First, how much do you know about telescopes? Be honest with yourself. Chances are you wouldn't be reading this article if you felt you already knew all there was to know about them. Do you really understand enough to buy a telescope with no hand-holding from the

seller? If you feel 100 percent certain that you already know the type, make, and model number of the telescope you want, then you're in a good position to shop for price and not support. On the other hand, if you need help from the seller to determine what you want, you need to find a knowledgeable dealer.

Second, how do you like to do business? In an ideal world, you'd just go to your friendly local telescope store and spend an hour or two talking to a knowledgeable clerk while inspecting a full line of makes and models on display, comparing them for price and performance. It's a difficult decision, and the clerk gives lots of helpful advice and asks you questions that help you clarify what you want to do with the telescope.

Finally you make up your mind. "Okay, this is the model I think I'd like." The clerk brings a sealed box from the stockroom, and together you open it and inspect the contents. The clerk shows you how various parts fit together and checks that everything is working perfectly. He then helps you repackage the instrument, writes up the sales slip, fills in the guarantee cards, takes your personal check, and helps you carry the box out to your car. As you drive away, the last words you hear are, "If you find anything that's not right, bring it back and we'll take care of it for you." That's the kind of help that mail-order dealers simply can't offer.

But maybe there *isn't* a telescope store in your town. What then?

Well, fear not. There are superb mail order telescope retailers who'll deal with you fair and square. It's not hard to tell which are the good ones. Just as the clerk in your local store knows his stock and offers good advice, good mail order firms know their stock, too. They'll do their best to help the customer long-distance. You'll probably sense the difference right away: they want to make sure you understand what each make and model of telescope can do and which is best for you.

Third, are you sure you know what you're actually buying? Model numbers, for example, can be confusing. In the hypothetical Super-Duper 1000 line of telescopes, the model 1022 is a telephoto lens with a camera adapter, the model 1020 is a spotting scope with one eyepiece, and the model 1024 is the telescope with fork mount, drive, three eye-

pieces, and carrying case. If you want the model 1024 telescope, make sure you haven't been quoted the price of the model 1022 telephoto lens or a stripped-down model 1020 without eyepieces or carrying case.

Furthermore, ask the dealer specifically what is included and what is not — don't just go by the picture in the ad! Then ask for a letter confirming what's included in the price you've been quoted. Even a reputable dealer may balk at spending the time to write a letter to you, but he or she will not refuse to comply. And don't send your check or money order (or offer your credit card number) until you receive the letter and have read it. Don't find out too late that the too-good-to-be-true price you've seen advertised really was too good to be true.

As for delivery times, you should be aware that the Federal Trade Commission protects you as a mail order buyer. You have the right to expect delivery within thirty days (unless otherwise specified) and have the right to get your money back — all of it — if the merchandise is not delivered. Last year's Halley-induced demand for telescopes produced back-order problems for some telescope dealers, but things are better this year. If a dealer has the telescope in stock when you order it, there should be no delay in delivery. Ask before ordering, and get the delivery time specified in writing along with the price. It might not hurt to check the dealer's reputation with the local Better Business Bureau, especially if you're ordering from a distant city.

One final hint: "Return within 5 days for full refund" may mean that the equipment must be *back in the dealer's shop* within the specified number of days. If you're not satisfied with your purchase, return it "certified" with "return receipt requested," or via a carrier with whom you can verify the date of delivery — and insure your parcel! *Caveat emptor!*

Buying a telescope is a lot like buying any high-tech consumer product — computers, VCRs, cameras, and the like. It's easy to find outlets, but it's hard to find a really good salesperson. If you don't know what you want, do a little research before buying. And when you find a company that deals openly and fairly with you, stick with them, even if it means paying a little more.

Do-It-Yourself Telescopes ▶

"I built my first telescope when I was 13. . . . Yes. It was a 6-inch f/7 reflector. . . . Sure, I still have it. I looked at Mars with it two nights ago."

In this age of mass-marketed products, it's easy to forget an important option: building your own telescope. Amateur telescope making got its start in America in 1921 when Russell W. Porter wrote an article for *Scientific American* entitled "The Poor Man's Telescope." In it he showed how anyone could grind and "figure" the mirror for a Newtonian telescope to start a lifelong hobby observing the stars.

In the decades that followed, thousands of men and women from all walks of life followed Porter's lead. Telescope building enjoyed its heyday in the boom years following World War II. Indeed, many of today's leading telescope companies were founded in the 1950s and 1960s by do-it-yourself telescope builders.

The way to begin building a telescope is to find out what's involved. There are quite a few books on telescope making, plus *Telescope Making* magazine, published by Kalmbach. Three recent books offer the best help for would-be telescope makers. I wrote *Build Your Own Telescope* to help the beginner. The book has complete plans for five telescopes plus pictures showing how to put it all together. *How To Make a Telescope* by Jean Texereau stresses precision optical work, including sections on optical windows, Cassegrain telescopes, even a computer program for reducing optical test measurements. *Standard Handbook for Telescope Making* by Neale Howard tells how to grind a mirror and build an 8-inch Newtonian reflector.

Many firms sell parts and accessories for home-built telescopes, including the all-important primary mirror. Sky Optical Company, for example, sells very reasonably priced mirrors for telescope makers ranging from 6- to 24-inch apertures. A. Jaegers Optics has mirrors for first-time telescope makers, ranging from 3 to 6 inches. Star Instruments sells mirrors from 10 inches to 24 inches. Coulter Optical Co. offers 13.1-inch to 29-inch mirrors for Dobsonians. Augen Optics offers super-stable 4-inch to 10-inch mirrors made from Zerodur, a special low-expansion

material, and Telescopes has mirrors with apertures from 4 inches to 20 inches.

Building a telescope is much more work than buying one, but there's a lot of satisfaction in studying tiny lunar craters, gazing at the rings of Saturn, or seeing a distant spiral galaxy in a telescope you've made with your own hands. And you'll save money, too.

Accessories

"Ever hear of Gillette? They make their money on the blades, not the razors. . . . Three eyepieces will do for a start. . . . Try photography next year. After all, you've got the rest of your life."

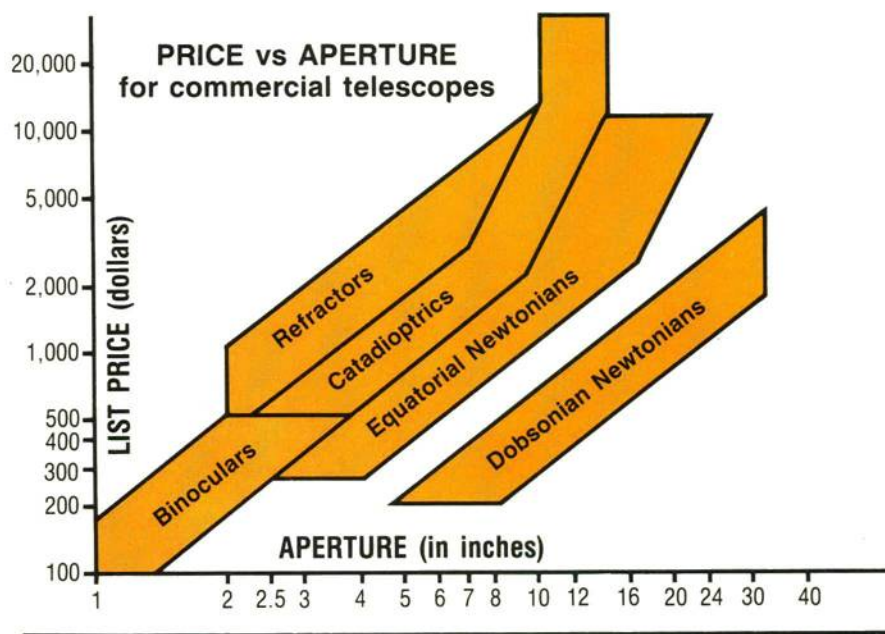
If a healthy after-market is the sign of a healthy hobby, then astronomy is a positively thriving field. There are many astronomical goodies on the market these days. Such temptation! All that good, useful stuff, neat stuff that makes observing easier, more fun, and more rewarding. Of course, fiscal prudence dictates that you acquire accessories slowly as your budget and observing skills grow, and as you need better tools to experience new areas of astronomy. There's no point in acting like a kid in a candy store.

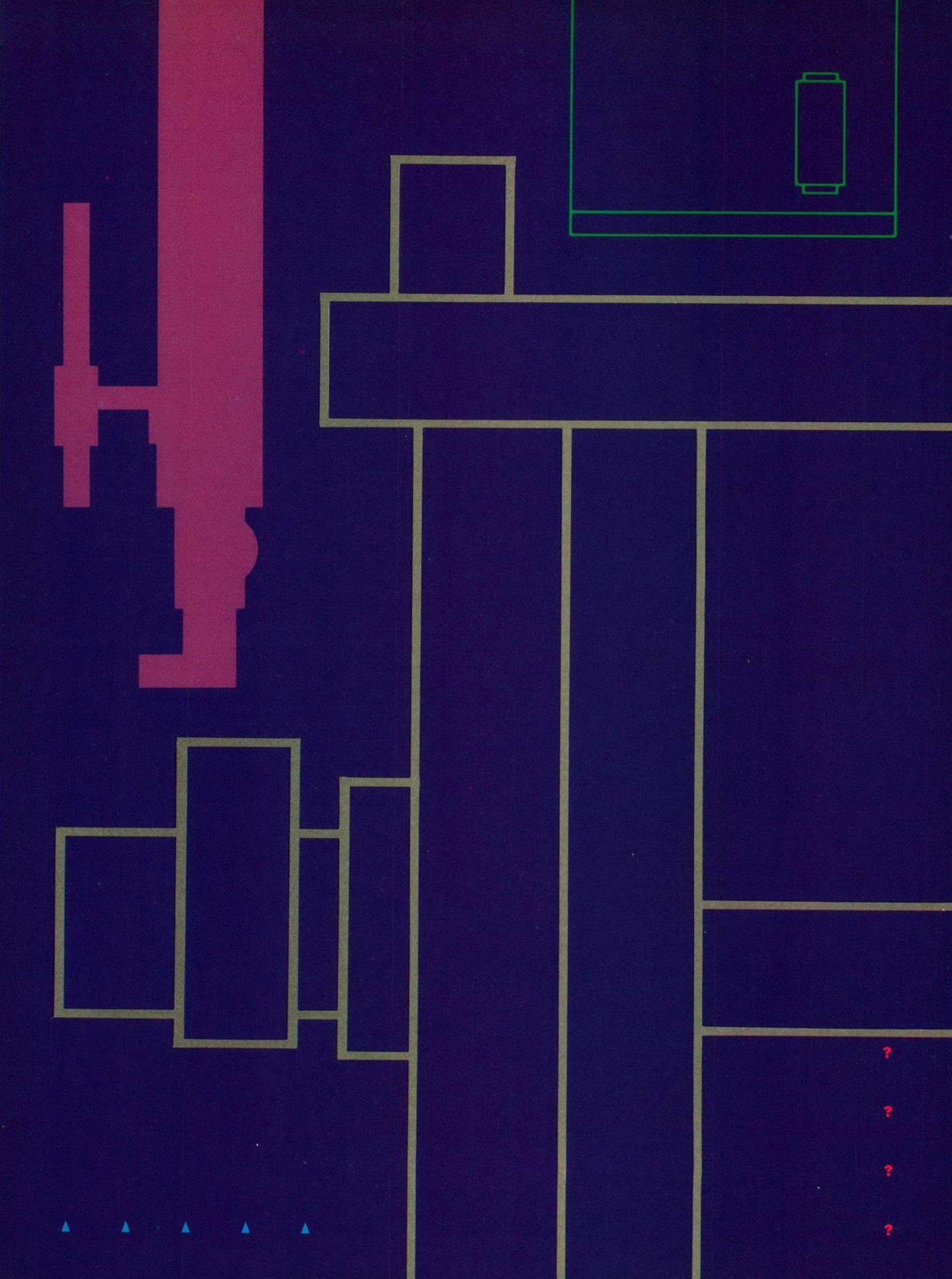
Eyepieces. Almost every telescope manufacturer includes two or three eyepieces with their instruments. Why should you want any more? To be perfectly frank,

though they're usually pretty good, those included eyepieces aren't always the best the manufacturer makes or has available. You may want only the best, or just something better. You may want a wider range of magnifications than you get with the eyepieces that came with your telescope, or you may want to enjoy dramatic "porthole-into-space" viewing with wide-angle and ultra-wide-angle eyepieces.

You might begin by investigating additional eyepieces from the company that made your telescope, then check a few independent manufacturers. Both Celestron and Meade offer extensive eyepiece lines, including improved conventional designs, wide-angle, and ultra-wide angle eyepieces. The leading independent eyepiece firm, TeleVue, has an extensive line of quality eyepieces, including super-sharp Plossls, Wide-Field, and the patented ultra-wide-field Nagler design. The Naglers are eyepieces you have to observe with to believe.

VERNONscope still offers the highly touted Brandon line of eyepieces. Edmund Scientific sells five eyepieces in its very reasonably priced RKE line, as well as a magnification-doubling Barlow lens. Orion, Lumicon, Ad-Libs, Cosmic Connections, and University Optics, to name a few, now offer competitive pricing on name-brand and house-label eyepieces.





Star Diagonals. While you're looking at eyepieces, don't forget another handy accessory: the star diagonal. A star diagonal works just like a 90°-elbow in plumbing — it takes the light around the bend. You don't need them for Newtonian or Dobsonian reflectors, but if you have a spotting telescope or an older refractor and don't have a star diagonal now, your stiff neck will love you if you get one.

All major equipment makers have name-brand star diagonals, so they're available from almost any dealer. Most Schmidt-Cassegrain telescopes include them. However, if you're thinking of getting some 2-inch barrel diameter eyepieces for low-power viewing, you may want to get a star diagonal with a barrel of the same size. Many of the 1¼-inch barrel star diagonals use a prism to bend the light, but one dealer, Lumicon, offers its own high-reflectance, silver-coated star diagonal for reduced light loss.

Finder Scopes. If your telescope didn't come with a finder, get one. A finder telescope mounted piggyback on your main telescope makes finding celestial objects infinitely easier. Most equipment makers include finders on their telescopes, but as is the case with eyepieces, they don't always install their top-of-the-line finder on their standard-model scope. But what's included may be fully adequate for your observing needs, so wait a while and get to know a bit about observing before you add a bigger finder.

Why should you upgrade to a larger finder? It will show you fainter stars and allow you to locate dim objects more easily. For deep-sky observing, the finder should have at least one-quarter the aperture of the main instrument. A 200mm (8-inch) telescope, for example, needs a 50mm (2-inch) finder. Check with your favorite Celestron/Meade/Bushnell dealer; you'll probably find a ready-to-install, large-aperture finder listed in the catalogue.

And there are more. Roger Tuthill, Inc. makes 50mm and 80mm finders that come complete with glow-in-the-dark crosshairs for easy centering. Edmund Scientific and Jaegers Optical Co. also offer several different models. For those big Dobsonians, look into using a 4-inch reflector from Thousand Oaks Optical or Chicago Optical.

For finding objects quickly, consider the Telrad® finder manufactured by Steve Kufeld. As a supplement to your regular finder, or as a stand-alone finder on a small Dobsonian, the Telrad® finder is tops. This device projects a red bullseye onto the sky, and though it does not magnify the image or make it any brighter, it allows surprisingly fast and accurate centering on sky objects.

Filters. Filters remove light, and a correctly chosen filter removes light that you don't want while transmitting light that you do want. For example, light-pollution filters (LPFs) block the dominant

wavelengths of light given off by outdoor lighting while transmitting some of the light from nebulae. These filters improve the image contrast for nebulae; that is, they darken the background sky more than they darken the nebula. While LPFs are rather expensive, they are effective in reducing the effects of light pollution.

Major manufacturers offer light-pollution filters as accessories, as do the numerous dealers that carry their product lines. In addition, Lumicon offers four specially designed light-pollution filters: Ultra-High Contrast, Deep-Sky, H-Beta, and O-III. Each type of filter is optimized for a specific job. The UHC is for observing nebulae, the Deep-Sky for galaxies, the H-Beta for extremely faint nebulae, and the O-III for very faint planetary nebulae. University Optics offers a line of LPFs for 24.5mm, 1¼-inch standard, and 2-inch eyepiece barrels.

Serious planetary observers frequently use colored glass filters to improve the contrast of faint atmospheric and surface markings. They also resort to neutral filters, or glare filters, to dim the glare when they're examining our nearest neighbor in space, the Moon. Colored and neutral filters are available from University Optics, Lumicon, and many other telescope and camera dealers.

Solar Filters. Daytime astronomy is solar astronomy. The Sun is a fascinating and ever-changing object to observe — but watch out! The Sun's image can burn a hole right through your telescope, not to mention your one-and-only pair of eyes. For safe solar observing you should use safe solar filters. Avoid the dangerous "black glass" kind. These allow the full heat of the Sun to pass through the telescope, then absorb it in a thin, dark glass. Instead, use reflective solar filters that cover the aperture and reflect away most of the solar heat.

Solar filters are a standard accessory available from most manufacturers and their dealers. Two independent firms offer reflective solar filters: Roger Tuthill, Inc. and Thousand Oaks Optical. Tuthill's filters are coated pieces of thin Mylar plastic and have become something of a standard for such filters. They enjoy an excellent reputation among solar eclipse observers. Thousand Oaks has both Mylar filters and glass filters. The Mylar filters consist of two layers of aluminum; the glass ones employ a reflective alloy of nickel and chromium.

Portable Power. How long can an extension cord be? If you're observing up in the mountains or out in the desert, the answer is, "Not long enough." Getting power to your telescope's drive motor can be a problem. But not to worry: Digitrak, Orion, Roger Tuthill, Inc., and Davionx all offer portable 60 Hertz power supply units. Some plug into an auto cigarette lighter and others run from internal rechargeable batteries.

To add declination slow-motion or

variable-speed tracking in right ascension, check your local dealer for manufacturer-supplied add-ons. Roger Tuthill and Jim's Mobile supply add-on drive units of their design. Jim's Mobile also offers electric focusing units for Celestron, Meade, and a variety of Newtonian telescopes. Hands-off focusing eliminates the annoying wobble and shake that often makes focusing these instruments so frustrating.

Star Atlases. Star charts and observing guides are important accessories. After Norton's *Star Atlas* passed into oblivion, there weren't many good guides for beginners until last year. Now there are three: *The Night Sky* by Wil Tirion and Ian Ridpath, a pocket-sized guide to the sky; the *Collins Guide to Stars and Planets* by Ian Ridpath and Wil Tirion, a bigger, thicker, and more complete guide; and *A Field Guide to the Stars and Planets* by Donald Menzel and Jay Pasachoff, one of the *Peterson Field Guide Series*. Astro Cards sells sets of 3x5 index cards that amount to a handy reference guide to the sky.

For more advanced observers, there's *Sky Atlas 2000.0*, with twenty-six big star charts showing stars down to 8th magnitude, and the accompanying *Sky Catalogue 2000.0, Volume 2*, with data on thousands of stars and deep-sky objects.

Where do you get these goodies? Some telescope dealers sell both the *Sky Atlas 2000.0* and *Sky Catalogue 2000.0, Volume 2*, as does Orion Telescope Center, Willmann-Bell, Inc. (send one dollar for their complete catalogue of astronomical books), Edmund Scientific, and Kalmbach Publishing Co. Your local bookstore is probably the best bet for the introductory sky guides.

No matter what kind of telescope you buy or build, it probably won't be long before you'll find yourself craving the "extras" that you didn't know you wanted. You'd like a higher magnification eyepiece and a lower magnification one, too; a camera adapter to hook onto your camera for astrophotography; a drive corrector and a guiding eyepiece to make long exposures; and a more powerful finder telescope to aid you in searching out faint galaxies.

The list could go on and on — but hold it! It makes sense to slow down and become familiar with your new telescope before investing in every doodad, gadget, and gizmo that can hitch a ride on the initial sale. Besides, if you get it all at once, what's left to hope for? Half the fun of amateur astronomy comes from thumbing through telescope catalogues and dreaming about what to order next!

Do What's Best for You

"You've decided what you want? ... That's wonderful. ... Sounds like a good choice to me. ... Thank you. I'm glad we've been able to help you. ... Goodbye."

— Richard Berry

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LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO
OF THE MONTH



Galaxy M31 and small companion M-32 in Andromeda. Phot by Martin Germano using a LUMICON Newtonian EASY-GUIDER™. 40 min. exposure using 103a-F film and an 8" f/5 Newtonian telescope with LUMICON Helical Focuser.

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Set 9 ea. 48mm filters (\$175 list) ... \$148
2" 1/4" adapter threader for 48mm filters ... \$20

H-ALPHA PASS FILTER

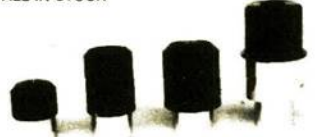


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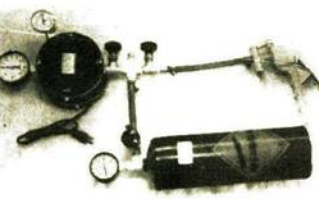
DEEP-SKY ASTROPHOTOGRAPHY

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actually there! and not just around 52 Cygni, but the
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NEW! Quartz Drive Meade 2080/LX3

The Meade 2080/LX3 with built-in quartz electronic drive system is positively the highest performance 8" Schmidt-Cassegrain telescope system available today.

FEATURES OF THE MEADE 2080/LX3

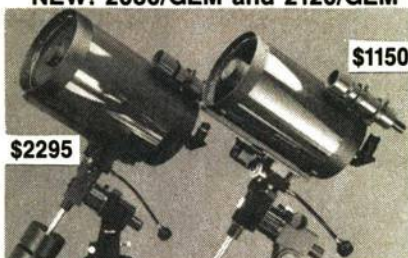
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The 10" Meade 2120/LX3 collects 56% more light than an 8" telescope for significantly improved viewing and astrophotography. It has all the features of the 2080/LX3 (see above.)

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NEW! 2080/GEM and 2120/GEM



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The Meade 2080/GEM and 2120/GEM telescopes include the same diffraction limited optics as the 2080/2120/LX3. Large, stable German equatorial mount with setting circles, slow motion controls on both axes, large 8x50mm finderscope, 25mm 1 1/4" eyepiece, integrated polar alignment scope, and heavy duty adjustable height tripod (hardwood for 2080, metal for 2120). The computer control provides automatic object location from an extensive software library of deep-sky objects.

4" MEADE 2045 w/table tripod \$695
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See Meade 2080/LX3 options
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(Model 628)

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(Model 628C)
6" f/8 with motor drive



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A Partial Eclipse of the Sun

by Robert Burnham

The Wanderers

As leaves turn color and drop and chilly evenings and frosty nights return, faithful planet watchers will find two of their favorites deserting the scene.

In late September and during the first days of October you can still spot **Venus** very low in the southwest right after sunset. Venus is brightest on October 1 (magnitude -4.6), but it then sets less than an hour after the Sun. Unless you have a viewing site with a southwestern horizon as flat as the ocean, you'll probably miss it. Venus will be visible in the predawn sky late next month, however, becoming prominent there during the coming winter and spring.

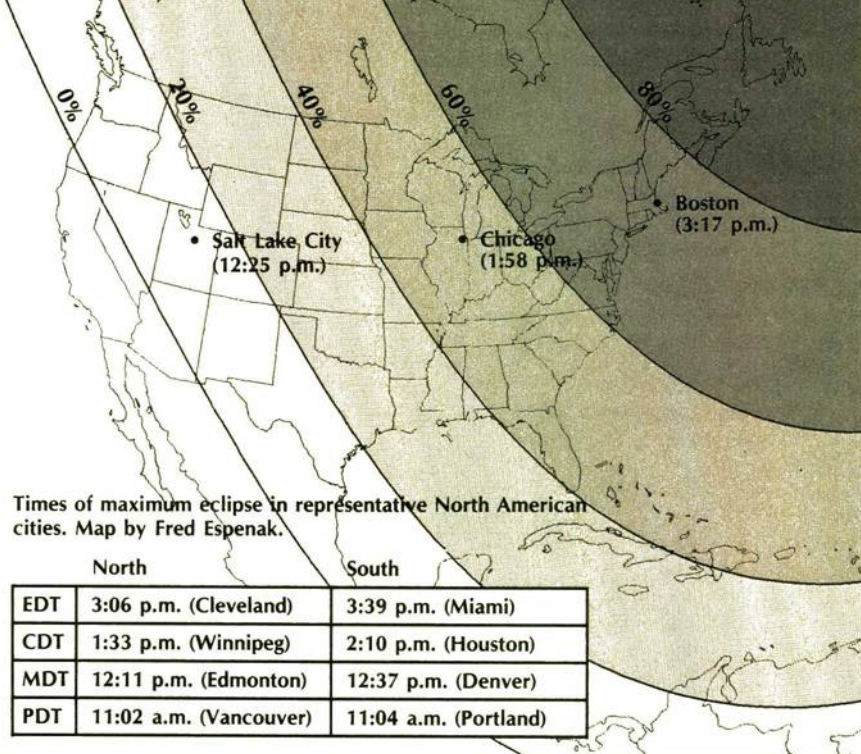
The other departing planet is **Saturn**. Although it has less than one-hundredth the brightness of Venus (magnitude 0.6), you should still be able to locate it without much trouble. Cream-white Saturn lies among the stars of Scorpius, which are mostly lost in the twilight. An hour after sunset go someplace with a good view to the southwest. Saturn lies about one hand's breadth above the horizon. It will remain visible through Halloween but by early November it sets too close to the Sun.

Around 8 or 9 p.m. step outside again and look south where you'll see two bright "stars." The whiter and brighter "star" (on the left) is **Jupiter**, at magnitude -2.8 . To Jupiter's right and two magnitudes dimmer is amber-colored **Mars**. Jupiter inhabits Aquarius, a dim constellation; Mars is moving eastward out of Sagittarius into Capricornus. Watch how far Mars moves toward Jupiter this month.

Last among the naked-eye planets, **Mercury** also lies in the evening sky this month but is all but invisible. You'll get a much better look at it in the morning

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Percentages of the Sun Eclipsed by the Moon, October 3, 1986



skies of November when it puts on its best appearance for the entire year.

October's Full Moon is known as the Hunter's Moon (see last month's Skylore). Many bird watching enthusiasts like to stare at it with binoculars and spotting scopes, trying to glimpse migrating birds flying in front of its disk.

Regrettably, the Moon will interfere with views of the **Orionid meteor shower**. Derived from Halley's Comet, the Orionids reach peak activity on October 21. Although the Moon will be at Last Quarter, many scientists and backyard astronomers will be observing during the wee hours of the 21st, hoping the recent return of the comet will lend strength to the shower. In a good year the Orionids, appearing to stream from The Hunter's upraised club, produce an average of 25 meteors per hour. Give them a try!

On October 3 a **solar eclipse** will occur in the North Atlantic and a partial eclipse will be visible at varying local times of day over all of North America, except for the West Coast south of 44° north latitude. Viewers in the Midwest, for example, will see slightly less than half the Sun covered up.

A safe way to view the eclipse is to punch a tiny pinhole in a sheet of heavy aluminum foil with the tip of a thin needle. Hold the foil facing the Sun and look on the ground where the foil's shadow falls. You will see a tiny Sun with

Top: The April 1986 solar eclipse as seen from Victoria, Australia. Photo by David Headland using Kodachrome 64 film, a 360mm telephoto lens with an orange filter, and a 1-second exposure. Bottom: A dawn view of moonset over Mono Lake, California. Photo by Vernon E. Grove, Jr.

a piece bitten out of it. (Do *not* look through the pinhole!)

On October 7 the Moon will cover the bright star Antares, which lies south of Saturn in Scorpius. This event will be visible only from the Pacific Coast of North America east to the Rockies and in the southern parts of the Gulf Coast states. Elsewhere you'll simply see the Moon pass close to Antares. Start watching with binoculars as soon as it gets dark enough to pick out Saturn, Antares' neighbor, in the southwest.

The Starry Sky

Many skywatchers rate October as the year's best observing month. The early sunsets mean that most of summer's stars linger in the west late into twilight. Waiting up only a few hours more brings many of winter's best sights into view in the east, and it's not too cold yet, even at northern latitudes.

The October Star Dome shows the sky when the brightest parts of the **Milky Way** have set. Yet if you travel even a short

Astronomy Equipment Directory 1986



A Special Advertising Supplement From Astronomy Magazine

Dear Reader:

Welcome to ASTRONOMY Magazine's *Astronomy Equipment Directory 1986* — the comprehensive source of information about suppliers of astronomy products and services.

The directory listings you'll find here were obtained from manufacturers, dealers and related companies that are dedicated to serving the special interest needs of astronomy enthusiasts. The information they've provided is designed to help you select products which will enhance your enjoyment of astronomy.

We hope you'll find this buyer's guide useful. Be sure to save it, so you can refer to it when making decisions about the purchase of astronomy products. And, don't forget to mention it when contacting suppliers — so we can all determine how well *Astronomy Equipment Directory 1986* is doing its job!

Best regards,
ASTRONOMY Advertising Staff

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* The information in these listings was provided largely by the manufacturers and suppliers. We have done our best to be all-inclusive and regret any omissions or errors.

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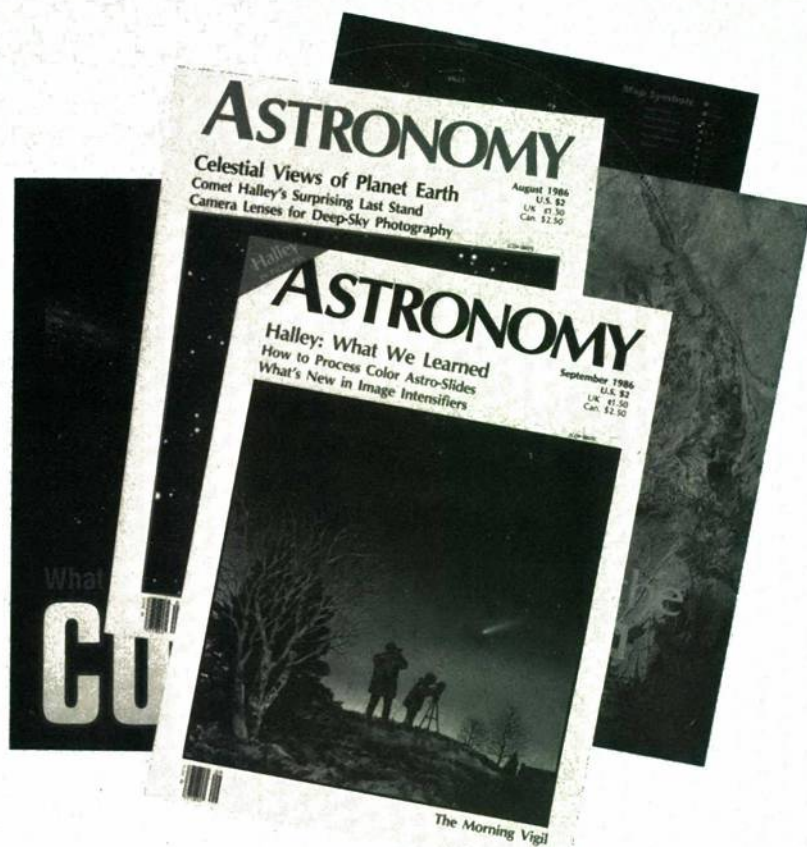
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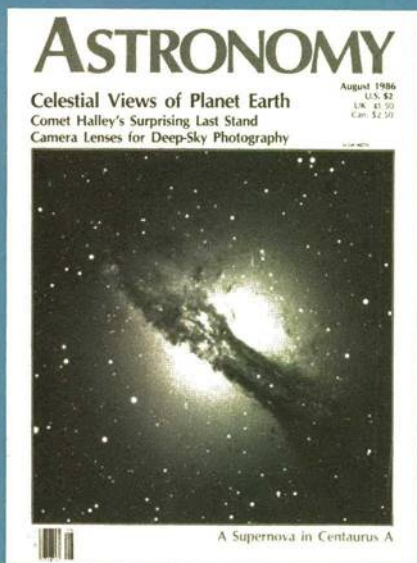
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October Night Sky



New Moon
October 3
2:55 p.m. EDT



First Quarter
October 10
9:28 a.m. EDT



Full Moon
October 17
3:22 p.m. EDT



Last Quarter
October 25
6:26 p.m. EDT

- 1st** Venus is at greatest brilliancy (magnitude -4.6) but lies so low in the evening sky that it is difficult to see.
- 3rd** New Moon is at 2:55 p.m. EDT. An annular-total eclipse of the Sun occurs in the North Atlantic between Iceland and the southern tip of Greenland. It is visible as a partial eclipse over all of North America except the West Coast south of latitude 44° north.
- 7th** The Moon is closest to Earth at 5:52 a.m. EDT: 367,189 kilometers. The Moon passes 5° south of Saturn this evening and soon thereafter occults the star Antares.
- 10th** First Quarter Moon is at 9:28 a.m. EDT.
- 11th** The Moon lies just to the east of Mars.
- 14th** The Moon and Jupiter form a close pair this evening.
- 17th** The Moon is Full at 3:22 p.m. EDT, and a total lunar eclipse occurs for observers in the Eastern Hemisphere. A partial eclipse will be seen in Labrador and Newfoundland.
- 21st** Mercury is at greatest eastern elongation from the Sun, but the planet is all but invisible. This is also the date for the peak of activity of the Orionid meteors, a shower derived from Comet Halley. Observe during the predawn hours.
- 23rd** The Moon is farthest from Earth at 1:38 a.m. EDT: 405,062 kilometers.
- 25th** Last Quarter Moon is at 6:26 p.m. EDT.

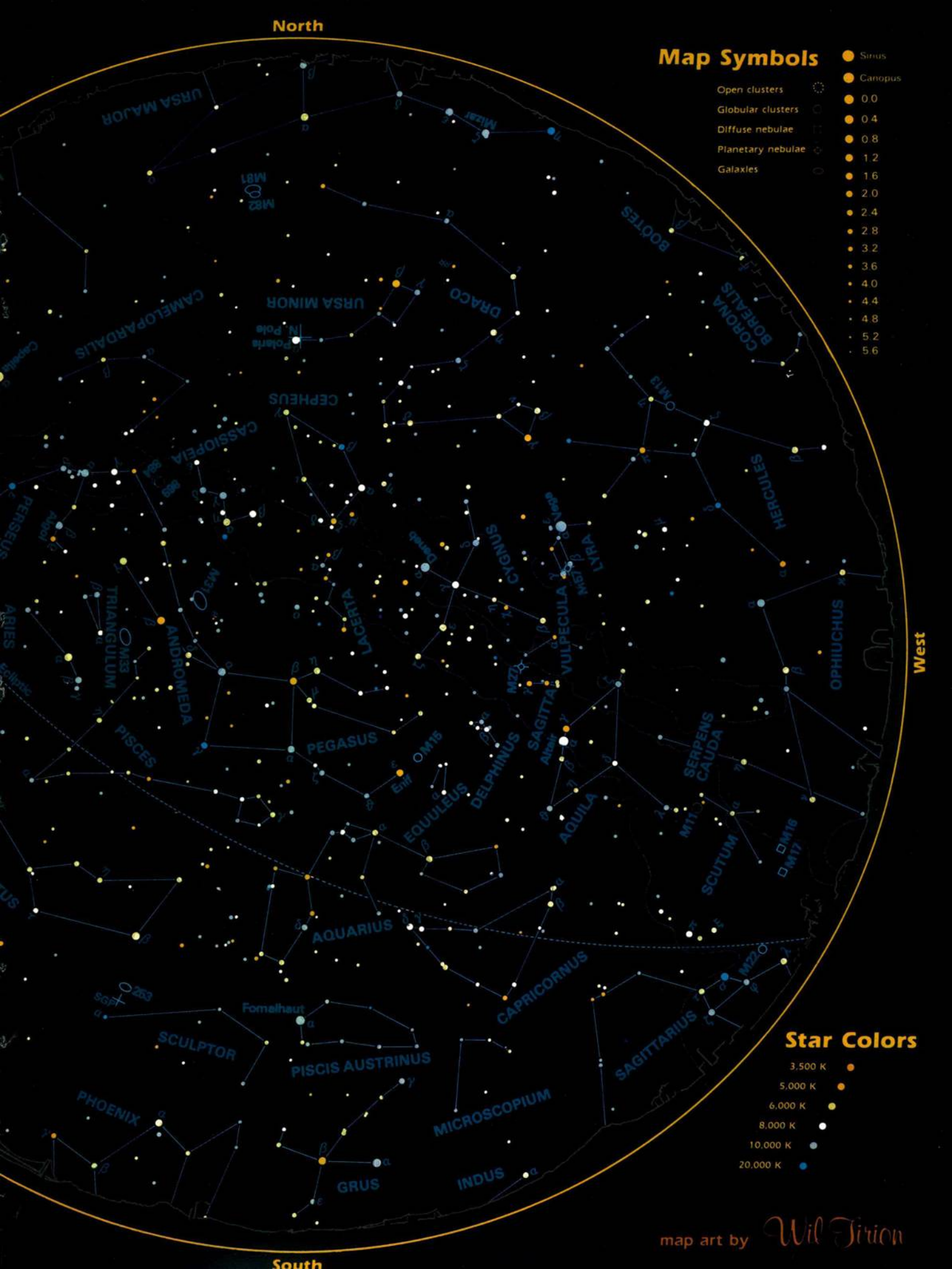


Looking southeast after sunset,
October 14

East

The
Star Dome
shows how the
sky looks at:

11:30 p.m. on October 1
10:30 p.m. on October 15
8:30 p.m. on October 31



North

Map Symbols

- Sirius
 - Canopus
 - Open clusters
 - Globular clusters
 - Diffuse nebulae
 - Planetary nebulae
 - Galaxies
- 0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6

Star Colors

- 3,500 K
- 5,000 K
- 6,000 K
- 8,000 K
- 10,000 K
- 20,000 K

map art by Wil Tirion



A twilight view of Venus, the crescent Moon, and Mercury (lower right), taken on June 9, 1986. Photo by Brian Skiff, who used a 50mm lens and Kodachrome 64 film.

distance out from town, what remains is plenty impressive. The Milky Way climbs up from the trees in the southwest, passes a few bright summer stars, divides in two, and then rejoins high overhead. From there it heads toward the northeast where it flows down to greet the early-rising stars of winter.

Three bright stars lie in the western part of the Milky Way. Forming a large asterism called the **Summer Triangle**, the three are Vega in **Lyra** the Lyre, Altair in **Aquila** the Eagle, and Deneb in **Cygnus** the Swan. Diminutive yet distinctive, Lyra represents the Lyre of Orpheus, legendary for its beautiful tone. Cygnus, also called the Northern Cross, is easy to trace, but Aquila requires a little care. How appropriate it is to find an eagle and a swan flying south in the fall!

Overhead, the small constellation resembling a child's drawing of a house, with its gable pointing toward the pole star, is **Cepheus**, a mythical king of Ethiopia. The star marked Delta (δ) is a famous variable star that changes brightness by almost a magnitude during its 5½-day period. Next to Cepheus sits Queen **Cassiopeia** on her throne. Near the star Beta (β) in Cassiopeia a supernova exploded in 1572, and showed Renaissance astronomers that the heavens were not as unchanging as the ancients had taught.

Next to Cassiopeia stands **Perseus**, in mythology the slayer of the Gorgon and rescuer of **Andromeda**, who is conveniently nearby. Andromeda was the daughter of Cassiopeia and Cepheus. The hazy patch of light located near the central region of her constellation is M-31, the Great Galaxy of Andromeda, a twin to the Milky Way that is 2.5 million light-years away.

Between the glittering stars of Perseus and Cassiopeia lies another dim and misty spot. Binoculars reveal a striking pair of open star clusters known as the "Double Cluster." Below Perseus (as you face northeast) is **Auriga** the Charioteer with its bright star Capella.

Now turn and look south. Below the Milky Way and filling half the sky is a vast, dim region best appreciated from a dark, rural site. Known loosely as "The Water," this region is filled with constellations of sea creatures. Let's begin our voyage here with the zodiac, which is easy to pick out since Jupiter and Mars point the way.

Amber Mars nestles between the setting stars of **Sagittarius** the Archer and the broad triangle of **Capricornus** the Sea Goat. Faint **Aquarius** the Water Carrier plays host to bright Jupiter and resembles a bent pair of pince-nez eyeglasses. East from Aquarius sprawls **Pisces** the Fishes.

Pisces is large, but you can easily locate it by first finding the circlet of stars south of the Great Square of **Pegasus**, Perseus' flying horse. Then follow the line of stars marked on the map eastward to Alpha (α), called Alrisha, the "knot" in the cord tying the Fishes' tails together. Look just east of the Great Square to find the other Fish, a loose zig-zag of stars.

This ends the zodiacal part of The Water since **Aries**, the next group east along the zodiac, is a ram and **Taurus**, just poking over the horizon, is a Bull. Directly below Alrisha, however, is **Cetus** the Whale, the sea monster from whom Perseus saved Andromeda. The star named Mira ("the wonderful") in Cetus is a variable star that dims from 3rd magnitude to 9th and returns to 3rd magnitude in about a year. (This month, however, Mira is at 9th magnitude, well below naked-eye visibility.) Mira's variability was discovered as long ago as 1596.

West of Cetus and south of Jupiter, a solitary 1st-magnitude star stands like a beacon. This is Fomalhaut in **Piscis Austrinus** the Southern Fish. Fomalhaut means "the mouth of the fish," and the fish itself forms a banner pointing west toward Sagittarius. Piscis Austrinus was originally depicted as lying on his back and is supposed to be drinking up the entire stream from Aquarius' water jar.

Only one constellation in The Water lies north of the zodiac, but it's a delightful little group that is easy to spot even from the city. **Delphinus** the Dolphin has a small rhomboid head — sometimes called Job's Coffin — and a curly tail spraying water as the animal leaps joyfully into the air.

Skylore

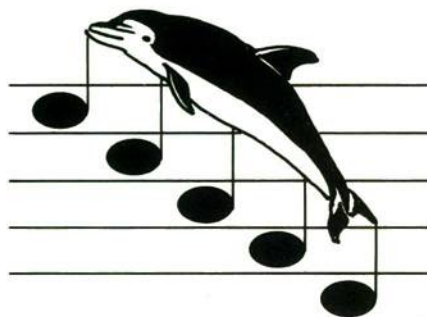
When Poseidon, mighty ruler of the sea, decided to take a wife, he wanted one who wouldn't mind living amidst damp surroundings. He therefore approached the sea-nymph Thetis, one of the fifty daughters (called the Nereids) of Nereus and Doris. Nereus was an old sea-god himself, wise in prophecy, with the strange gift of changing his shape however he wished.

From a different oracle Poseidon had heard a disturbing prophecy: If Thetis bore him a son, the son would turn out greater than the father. This nettled his pride and so he sought his mate elsewhere. He soon chose Amphitrite, another Nereid. She would have nothing to do with Poseidon, however, as she had taken a vow of celibacy. Fleeing into the mountains near the Pillars of Hercules, she refused all his advances until he hit upon a persuasive messenger to lure her back.

Delphinus was a dolphin of the mammalian variety (*Delphinus delphis*) and, like his bottlenose cousins who perform so delightfully in countless aquariums, he seems to have been exceptionally charming. Legend says

nothing about how he reached Amphitrite's hiding spot in the mountains, but get there he did.

One also wonders just what the winning argument was. Did Delphinus promise riches? (Ruling the ocean, Poseidon was a powerful deity and had collected much loot over the years by sinking ships.) Or was it control over the sea and its denizens? (Here, too, Poseidon was dominant, for he commanded the tribute and loyalty of cities on the land.) In any case, Amphitrite finally yielded to Poseidon's blandishments and, accompanied by the winsome Delphinus, departed the mountains for her briny destiny. In gratitude, Poseidon immortalized Delphinus in the heavens, where he can be seen on any clear autumn evening.



Poseidon and Amphitrite had three children, one of whom (Triton) provided the name for the planet Neptune's chief moon. (Neptune is simply the Roman name for Poseidon.) Neptune's other moon is called Nereid, collectively honoring the fifty daughters of Nereus.

Another well-known legend explains the celestial fame of this mammal by identifying Delphinus with the dolphin that rescued the famed poet/singer Arion from drowning. Arion was traveling by ship back to Corinth from a music festival in Sicily when the ship's crew decided to murder him for his prize money. Learning what was in store for him, Arion pleaded for the chance to sing one final song, which was permitted. The bard then took his lyre and sung a hymn so sweet that when he was thrown over the side, he was saved by a dolphin — in legend, all dolphins were music-lovers — and he was carried on to Corinth ahead of the ship.

Safely landed, Arion alerted the king who seized the ship and crew upon its arrival. The men, figuring the poet/singer was safely dead, swore that Arion had been so delighted by his reception in Sicily that he stayed behind. Arion then confronted them in person and described the murder attempt. The captain and crew, caught in a bare-faced lie, were promptly seized and executed for their treachery.



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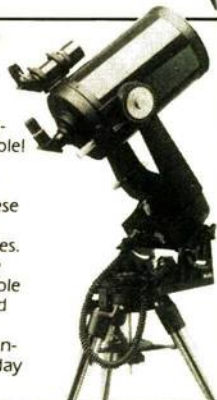
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A Dedicated Dabbler Captures the Sky

by John C. Waugh

I confess I've always thought that amateurs who make guided astrophotos are obsessive. But then I'm a dilettante astronomer who doesn't even bother with careful polar alignment. Oh, I suppose someday I'll take the time to align my optics, get a guide scope, figure out how to get the mount to point to that mythical spot in space .9° from Polaris, let the scope cool for a few hours, blow dry the dew away, and take some shots of distant galaxies and nebulae like you see in telescope ads.

But in the meantime I've done okay with some jury-rigged equipment, serendipity, a modicum of persistence, and the local overnight photo lab.

My life is sprinkled with the confetti of a long and flighty romance with the night sky: a pair of cheap binoculars here, a view from a mountain top there, an occasional effort at making my own equipment, and a commercial scope bought with the insurance settlement from a car accident.

I've always been interested in science, as well as nearly any other field you can name, from juggling to judo. But nobody can be an expert at everything, so I have become a dedicated dilettante — a bit of an expert on everything.

(The high point of my career as a dabbler was when I took an old version of the Medical College Admissions Test and scored in the 99th percentile on the general knowledge section.)

When I was 12 I ordered a mirror from the glittering Valhalla of boy scientists, the Edmund Scientific Company. It was just an inexpensive spherical mirror, but its 6-inch diameter put me in the big leagues for my age. I'd considered grinding my own mirror, but even at that age I knew that my scattered intellectual indulgences wouldn't give me the time or patience for such exacting work.

My *modus operandi* was to collect a piece of wood here, a bearing there — things I would string together later, a bit at a time, into an equatorial mount. It was made of ¾-inch plywood sections cut at

the angle for my latitude and bolted together in laminations to form the main block. On it were pillow block bearings carrying a 1¼-inch steel shaft that threaded into a "T" pipe fitting with flange bearings, holding a second shaft at right angles.

I didn't have the ability to fabricate a clock drive, but I was able to cast some nice lead counterweights. The mount looked impressive though the overall effect, with a 72-inch long, heavy cardboard tube, counterweights, and primitive friction brakes on the axes, was one of shaky utility.

Many new celestial sights revealed themselves, but what I remember most about that telescope was the impression it made on my mother one night when she saw a near-total eclipse of the Moon through a low-power eyepiece. Even now she remarks about that night when the Moon really seemed spherical, to hang in space, a combination of optical and color factors that made for a particularly three-dimensional look. Plus something else, the quintessence of amateur astronomy: a subtle blending of perceptions, feelings, discovery, newness, and being there that makes the experience so much more than the best pictures through the biggest telescope.

There followed a long hiatus from astronomy when so many other things impinged on my life. Model rocketry, archery, school, friends, bowling, science fiction, girls, college, marriage, and so on. Now and then incidents tugged the strings of memory — the stars from 7,000 feet on Mount Wilson, a look at Saturn through a 20-inch refractor, a college pal who was grinding an 8-inch Cassegrain mirror.

While teaching Earth Science at a military academy, I found time to build another telescope. This time it was an 8-inch combination Cassegrain/Newtonian using a mirror set I'd purchased with convertible spider to switch secondaries without losing alignment. The big spray-painted electric blue tube looked impressive in my classroom. Having

acquired a radial arm saw, I threw together a wooden alt-azimuth tripod mount with pipe fitting bearings while I worked on an equatorial using a surplus arc welder.

This mount was rock-solid with 3-inch steel pipe legs and a massive wheel bearing from a junked piece of farm equipment as the polar axis. A 12-volt car windshield wiper motor turned a welded pipe fork mounting via a heavy brass worm gear that my wife had discovered in a surplus yard. I hadn't worked out a way to get a true sidereal rate from the wiper motor; a rheostat served to approximate it by eye.

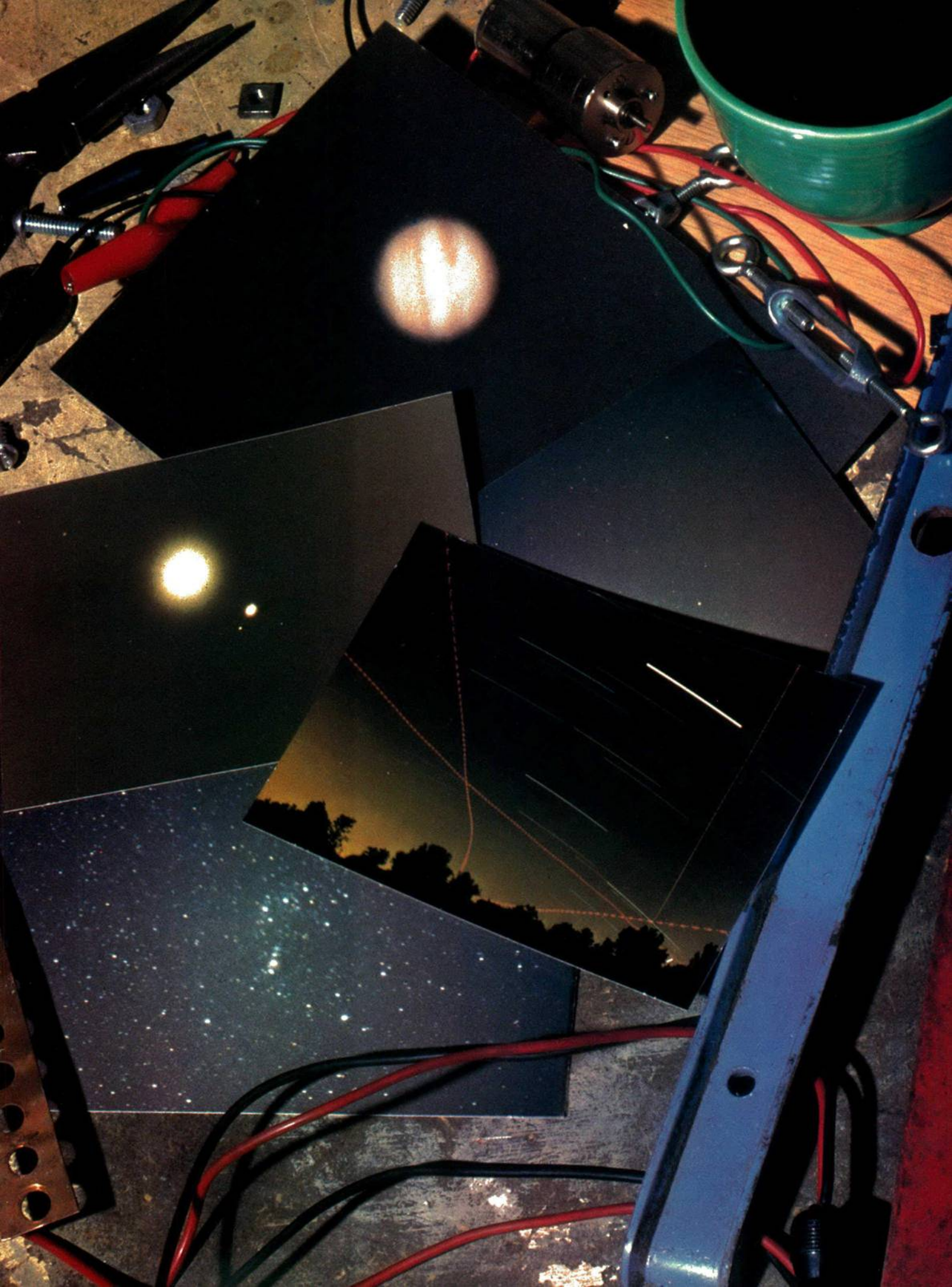
I never did use that mount much anyway. It was just too darn heavy for a professional dilettante to drag out into the open very often, especially since I had begun teaching computer programming. (As you might imagine, the entire computer field is a siren call to the disparate mentality.)

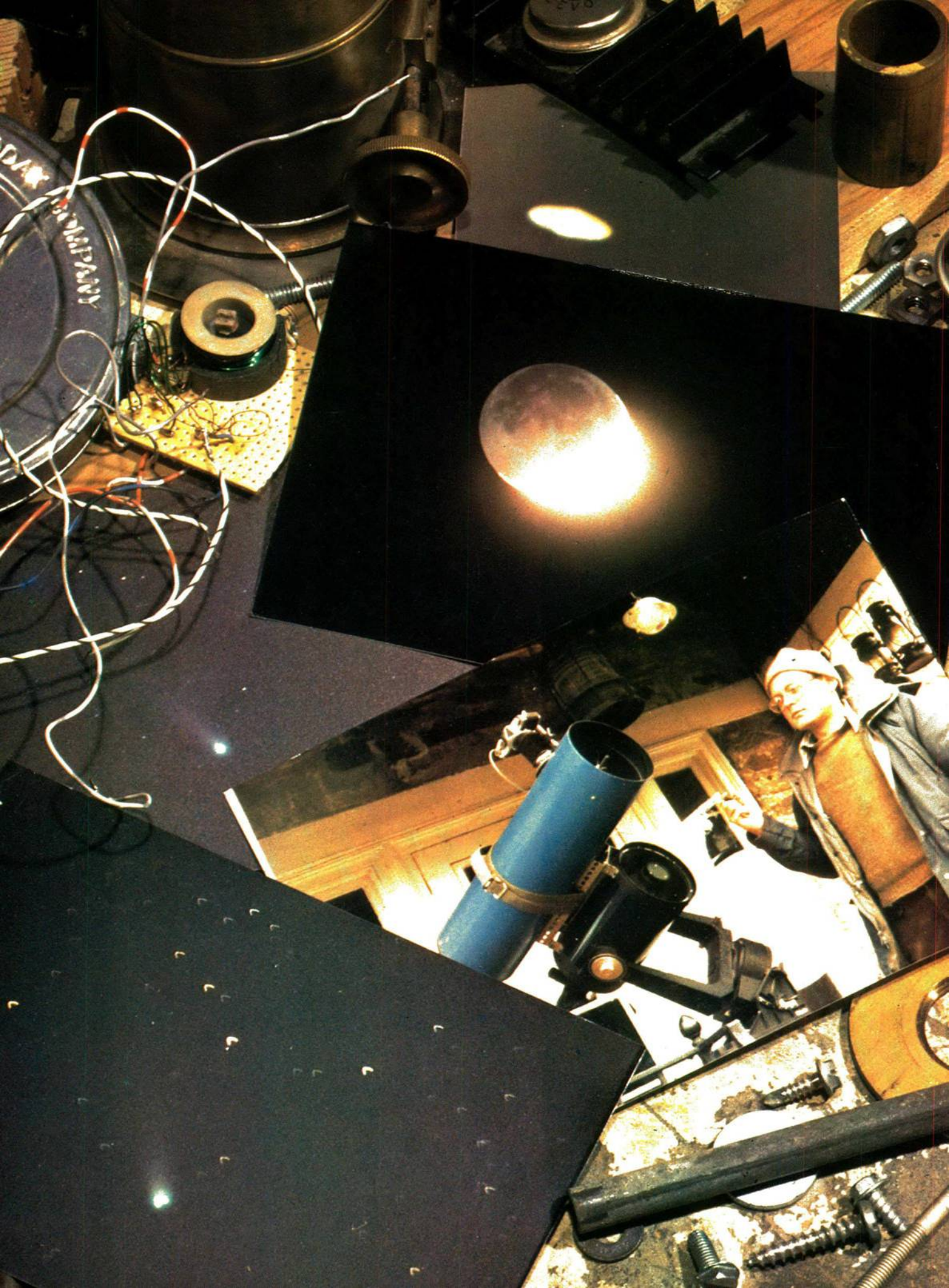
Then one morning I was nearly killed by a garbage truck as it returned the vintage Jaguar I had spent a whole summer restoring to its former wrecked state. The accident wasn't my fault, and I felt justified in spending some of the settlement money to see some different stars for a change. I bought an 8-inch SCT.

This was it — the dream scope. Clock drive, setting circles, fine adjustments on the axes, and such a short tube. The whole thing was light enough that I could keep it in the living room and drag it outside (after my ribs healed) with little effort. Fortunately the tripod legs could be coaxed through the front door without needing to be collapsed or removed from the telescope. Little things like that can destroy the best intentions of a dilettante.

Now came astrophotography! The Orion Nebula — the Owl Nebula — Andromeda — clusters — comets. I ordered a T-adaptor for my camera along

The bands of Jupiter, an overexposed Venus, star trails and "worm tracks," and the wonderful Rosette Nebula. All photos by John C. Waugh.





with an eyepiece projection tube. The universe was mine!

Of course I knew about the demands of professional astrophotography: the right films, the guiding, precise polar alignment, windless nights, cooling the tube, and all the rest. But I pushed all that to the back of my mind. It couldn't be all that difficult. After all, I had a *clock drive* now.

And I wasn't completely wrong. My debut in astrophotography had been serendipitously timed to coincide with the introduction of Kodak 1000 ASA color film. What a marvel! Film fast enough to take snapshots of the universe. My very first attempt was a conjunction of Venus and Saturn during which I managed to grossly overexpose an entire roll.

But I learned, too, that overexposing one celestial body might reveal an other-

Of course, standard lab printing equipment isn't set up to handle pictures of little specks. If they print it at all, it'll come out looking like the steady state theory. (You know, there's a star out there somewhere in every direction, so the night sky ought to be white.) For this problem, I've found that "Please print star pictures with sky dark" does the trick.

Maybe the fellows at the lab have come to recognize my envelopes. Maybe they're actually excited about seeing occasional pictures of Jupiter, Saturn, and Halley's Comet come tumbling off the print dryer. Maybe dogs have wings. Whatever the case, persistence works, and even the absolute Philistine understands the instructions, "Please print negative #5 DARKER than the enclosed print (also return the enclosed print, please)."

like an entirely new object in the sky. I snapped a few pictures and again was pleasantly surprised to see that gross overexposure can be beautiful. A dramatic picture resulted, with the blazing crescent destroying all detail on the bright part of the Moon and the maria clearly visible across the dark face.

Speaking of Halley's Comet, I was, of course, sufficiently motivated to get out shortly after dusk during the first phase of its appearance. (Even a jaded dilettante has his pride.) Naturally I took plenty of pictures. Some shots were made with a standard 50mm camera lens with the camera strapped on a homemade rack on top of the SCT. Some were made using a 105mm telephoto lens; some were taken at prime focus.

I also rigged up a special arrangement



wise invisible one. While Venus' subtle phase was entirely lost in the blossoming glare along with any detail of Saturn's rings, lo and behold there was Titan, Saturn's largest moon, appearing only in the most overexposed prints. This was all I needed. Here was discovery, surprise, excitement. I was hooked.

It's not as if I was suddenly ready to devote hours waiting for tube temperatures to equalize and to process specially prepared films. (I get aggravated if it takes more than ten seconds to get the focus right.) But I began to seek those shots that might give fast results on fast film.

I take all my film to the local quickie photo lab. Ever since some nasty experiences where they printed everything on the roll except the astrophotos (yes, I do usually intersperse astrophotos with family snapshots and tourist pictures), I have been careful to print my own special instructions in the little box so marked on the lab envelope. Phrases like "Please print all pictures including star photos" do the job. But don't make it sound desperate or demanding, like "Print the star negative with the little dots!" That's like putting "Careful! Contains fine china!" on a parcel post package.

Saturn, the Moon bathed in earthshine, the ultimate in piggybacking, and two different views of Comet Halley.

Now the wall near my desk is cluttered with my very own astrophotos. Adequate pictures of Saturn's rings at 200 power; pictures of Jupiter snapped on nights when the atmosphere was wavering (with some high-tech image processing by Xerox); constellations taken with the camera mounted on just a plain tripod.

One of these tripod photos was a snapshot of Orion taken with Kodak 1000 ASA film with a 50mm lens at $f/1.4$, using a 30-second exposure. I was pleasantly surprised to see that the dark notch of the Horsehead Nebula was clearly visible. And in the upper left corner of the print was the Rosette Nebula, which I never even knew existed until I found it on this print, and then checked a star map. I thought that maybe the boys at the lab weren't washing their prints properly.

One of my favorites is a picture of star trails and Jupiter after leaving the shutter open for fifteen minutes. With color film, the distinctive colors of the trailing stars are dramatically visible. And as an additional bonus, there are many dotted lines vectoring into the horizon like little worm tracks. (We live near an airport.)

The Moon, of course, is an excellent subject, and so patient a poser. And sometimes it can be surprising, too. One night I was out taking pictures of Halley's Comet. There was the crescent Moon, with earthshine so bright that it seemed

worthy of a once-in-a-lifetime event. I knew that a 105mm telephoto wasn't going to give me much of a view, and that the telescope's $f/11$ ratio and narrow field wouldn't be that great either. So what else did I have around? Why, an $f/4$ Newtonian scope, of course!

Collecting my resources, I fabricated a camera for the Newtonian using an abandoned Miranda camera body, close-up bellows, and some pipe fittings. There was a lot of drilling and grinding with minimally effective tools. But what about a clock drive? With remarkable foresight, Fuji Film Co. had introduced its 1600 ASA color film just in time for Halley's return, but even at that speed, would I be able to get a good snapshot through the scope without an accurate drive? I thought not.

Fortunately I'd made a really heavy-duty camera rack out of angle iron to mount my Pentax on the SCT, anticipating using telephoto lenses and perhaps also mounting a guide scope at some point. Somewhat tremulously I experimented with strapping the Newtonian, with at least twice the bulk, on top of the SCT. Piggyback with a capital P!

The drive didn't complain too much. And, blessing of blessings, the axis clutches seemed able to hold at the angle I needed without counterweights. I don't recommend this system, however, to any but the foolhardy and desperate.

Then came a nice clear night. Clear, but not calm. The wind was gusting nastily. Not wanting to lug my equipment very far for pictures that might be ruined by wind vibration, I broke the first rule in the astrophotographers' handbook and set up on my back porch. There was a good view of the western sky, and I could just barely see Polaris for alignment. Plus it was very convenient to pop into the house out of reach of that freezing cold wind!

Company stopped over that evening, and I remember running up and down stairs, advancing the film, clicking the shutter, and running back inside to visit for the five minutes or so of each exposure. Lights were blazing in the house, but they were 180 degrees behind my line of sight.

The moment of truth came when the prints got back from the lab. I had

V-shaped ones were the longest exposures and consequently the most acceptable negatives. The boys in the lab must have said something like, "Look at this guy. Took twenty pictures of the same thing. Let's save him some money and just print the best ones."

Needless to say I rushed back in and ordered prints of the missing photos. "Please print with sky dark: #3, #7, #12."

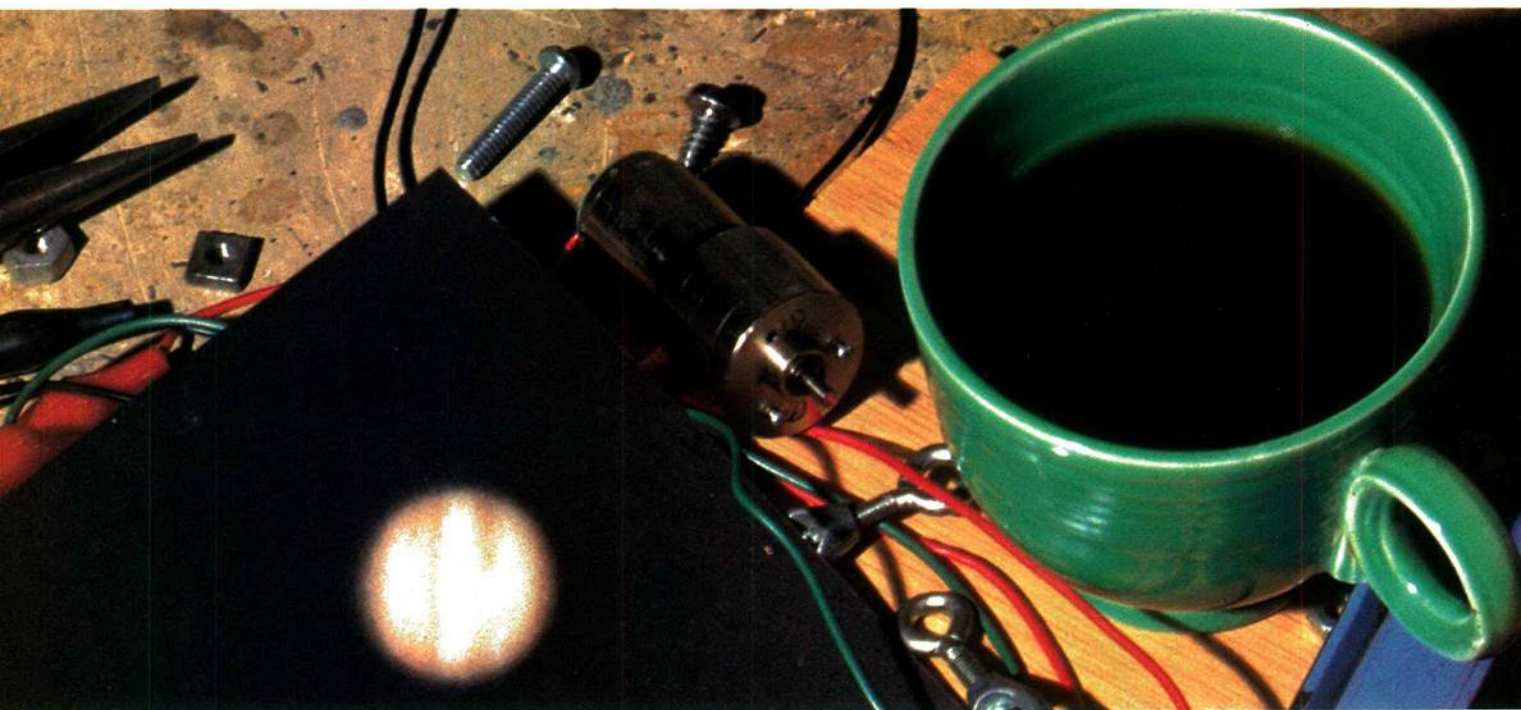
And there it was! One perfect exposure on the roll. One minute's worth of shining blue-white comet, the ephemeral trail streaming behind, seemingly streaking through the stars of Aquarius. There was a 3-minute exposure that showed the tail better, but the star trails were enough to be irritating. But one good photo was enough.

I had taken pictures with the 105mm

Nebula in Lyra. It's a small miracle that I even recognize this little constellation. It's hard for the true dilettante to get out at night, being frequently exhausted by the varied interests of the day. The Ring Nebula does get me out, though. Planets are okay, but they're kind of like the Moon all over again on a smaller scale. Gas clouds and galaxies are nice too. But the Ring Nebula — who'd ever think there was something like that lurking high up there on a clear, moonless night?

Every time I see it even dimly in my scope I'm impressed all over again. What a peculiar little hazy donut! The smallness itself is impressive, like a Bonsai tree.

I also like the Andromeda Galaxy. There it hangs, night after night, skirting through the trees. A hundred billion stars, perhaps a hundred billion planets, populated by who knows what. Perhaps someone is



modestly requested them to "Please print star photos with sky black," not mentioning that this was Halley's Comet! Peeking at the pictures, I saw a beautiful blue comet with a distinct tail, but the head was shaped like a little "V"! Wind vibration. The wind had set up a periodic vibration in the mount that caused it to wobble (overloaded as it was) in a fixed pattern.

Were there other photos taken when the wind had died down? Disappointingly there were not. What was I going to do? Show all my friends the comet pictures and have them ask, "What's that funny little 'V'? I didn't know comets looked like that."

Then, in the midst of misery, I realized that there weren't enough prints in the envelope for the whole roll. I looked through the negatives. There they were, a few exposures that looked quite good! Why hadn't they printed them? Well, the

and 50mm lenses as well, and these came out fine. The comet with its tail was plainly visible, if you knew where to look.

So I had a series of shots to impress friends with. I'd show them the 50mm shot first: "Oh? (squinting) Oh, yes. There it is. That's Halley's Comet, eh?"

Then the 105mm shot. Let them find it for themselves. "Ah yes. It's quite plain there."

Then I'd hit them with the Newtonian picture and, honestly, most would let out a little gasp and be truly impressed.

Now that's true happiness to a dilettante. Many amateurs with more time, patience, and equipment got better shots of Halley's inbound orbit, but I got a pretty darn good one with just a bit of each. And again there was that feeling of me and the night, the mysterious sparkles in the sky blending existentially with myself.

My favorite sky object is the Ring

standing on a distant shore gazing up through weird-looking trees at a hazy blob, the Milky Way Galaxy, thinking of . . . me?

That's when my debt to the pros becomes evident. Without them, my imagination wouldn't roam over that starry shore, wouldn't know Andromeda was more than a dim challenge to my eyesight.

In a way, astrophotos, and the experiences they reflect, are like children. You see them all over the place, but there's nothing quite like having your own.

John C. Waugh, a computer programmer/curriculum developer/instructor for the Marlboro School District, lives along the Hudson River in Newburgh, New York. With a background in electronics, biology, science education, and computer science, he has written several articles on science experiments and computers, and a children's book, The Magic Rock.

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Guiding Magnification For Top-Quality Astrophotos

by
Barry Gordon

Monitoring the motion of a camera or telescope as it follows a celestial object and applying to it any corrections that are required is known as guiding. Deciding how accurately to guide and knowing whether you are meeting that goal during an exposure are major factors in determining the quality of your astrophotos.

Of the options for guided astrophotography, the piggyback technique is the least demanding and hence the best method to learn first. With this setup, a guided telescope carries a complete camera/lens combination securely mounted atop the tube. In this configuration, typical camera lens focal lengths are between 50mm and 300mm, with 135mm and 200mm the most popular.

One advantage of this method is that it uses a telescope with a fairly long focal length to guide a camera with a rather modest focal length. Since the magnification of the guiding telescope is higher than the magnification of the camera, tracking errors are more obvious in the guiding field and can be corrected before having too much effect on the photographic image. This gives the piggyback method considerable guiding leverage.

After mastering the basic techniques of guided astrophotography you will probably want to go after the more impressive images available only with much longer focal lengths. That requires photographing with your telescope, either at the prime focus or with a focal reducer. In both cases you'll have to relocate your guiding system to an off-axis guider or a separate guidescope.

How much guiding leverage do you need to get good results? That depends upon several things, including what you consider to be good results and how keen your eyesight is. However, we can set some pretty solid guidelines.

The guiding magnification necessary for good astrophotos depends on the focal length of the photographic system. To examine this in detail, let f represent the photographic focal length in millimeters. Experience indicates that the minimum magnification needed for guiding is about f divided by 12.5. It further turns out that

this is precisely what you get with a 12.5mm guiding eyepiece used in an off-axis guider for prime focus photography. (Clearly, since visual magnification is simply the ratio of objective to eyepiece focal length, the combination of prime focus camera and off-axis guider with a 12.5mm eyepiece must give a guiding magnification of $f \div 12.5$.)

What happens if you use the 12.5mm eyepiece and add to it a typical focal reducer that reduces the effective photographic focal length by a factor of .6? Since the eyepiece focal length remains unchanged, the guiding magnification is effectively raised to around $f \div 7.5$. This is a significant improvement, and one good reason for the popularity of the focal reducer. For top-quality guiding, however, most experienced astrophotographers advocate guiding magnifications of $f \div 5$ or higher.

(Don't be confused because $f \div 5$ is similar to the notation used to designate lens apertures. All it means is that, like lens aperture, guiding magnification can be meaningfully expressed as a fraction of focal length.)

Here are the guiding magnifications for several commonly used objective focal lengths.

Focal Length (millimeters)	Minimum ($f \div 12.5$)	Optimum ($f \div 5$)
900	72x	180x
1200	96x	240x
2000	160x	400x
3000	240x	600x

Just how precise must your guiding be, and how can you tell during an exposure whether you are meeting the required guiding precision?

First you will need to know how much precision to demand. The aim is to produce star images that are perfectly round. By examining many good and bad astrophotos, I have found that a drift of .04 millimeters in the image is acceptable as an initial value, so we shall adopt that as our image-drift tolerance. If you later decide on a different tolerance, simply substitute the new value in the formulas and generate the appropriate numbers.

What does .04 millimeters, or any other amount of image drift, imply about your guiding? With short focal length lenses we can tolerate considerable pointing, or tracking, error before the image drifts .04 millimeters on our film. With long focal length lenses, that much image drift results from far smaller tracking errors.

The standard formula for image size is:

$$s \approx A \times f \div 57.3$$

which for focal length f tells us the image size s in terms of our subject's angular size A , in degrees. But this is equivalent to the amount of image drift resulting from a given angular tracking error. If we simply invert the original formula to:

$$A \approx 57.3 \times s \div f$$

and plug in our chosen drift tolerance of .04 millimeters, we get:

$$A \approx 2.29 \div f \text{ (in degrees)}$$

$$\approx 8250 \div f \text{ (in arcseconds)}$$

This tells us the maximum allowable tracking error as a function of the photographic focal length in millimeters to produce images having less than .04 millimeters of drift. The tracking tolerances, in arcseconds, are:

Focal Length (millimeters)	Tolerance (arcseconds)
50	165
135	61
500	17
1000	8
2000	4
3000	3

At this point, let's consider the relationship between solar and sidereal tracking rates. Not all telescope drives run at the sidereal rate of 366 revolutions per year. A great many run at the solar rate of 365 revolutions per year. Will this make a noticeable difference while guiding?

To answer that question, we need to know the apparent sidereal rate relative to the solar rate. Since the stars make one extra circuit each year relative to the Sun, that rate is clearly 360° per year, or about .0000114077° per second. Substituting

this for A in our original image size equation, we get the trail length or image drift d that results from this rate difference in t seconds:

$$d \approx (.0000114077 \times t) \times f \div 57.3$$

$$\approx f \times t \div 5,000,000$$

This can readily be solved for t giving:

$$t \approx 5,000,000 \times d \div f$$

Continuing with our assumption of .04 millimeters as the limit on acceptable image drift, we can substitute this for d to get:

$$t \approx 200,000 \div f$$

This tells us approximately how often, in seconds, we must manually correct our solar drive to maintain the desired image quality. Let's see how many minutes that actually means for our set of common photographic focal lengths:

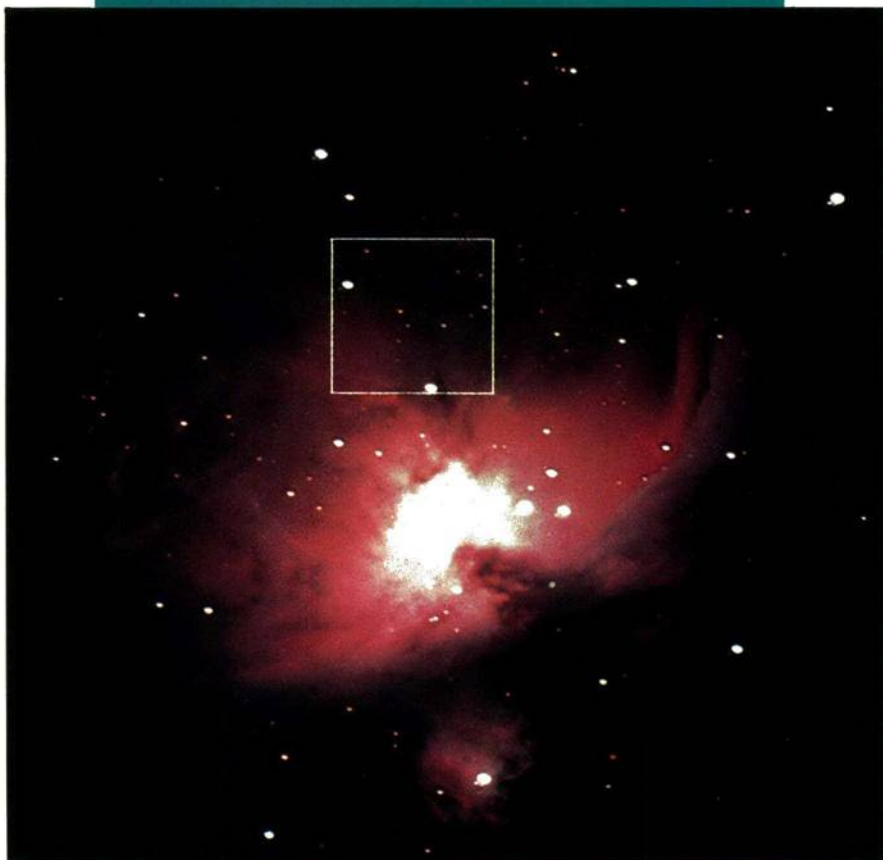
Focal Length	Minutes
50	67
135	25
500	7
1000	3
2000	2
3000	1

There isn't much of a problem with a 50mm lens; one correction per hour is hardly worth mentioning. But as focal lengths increase, so do the problems. A correction every minute or so, for the solar to sidereal rate adjustment alone, can become a real nuisance. Obviously, except for piggybacking short focal length lenses, a telescope drive that runs at the solar rate needs a drive corrector that has a permanent bias control to modify its standard output.

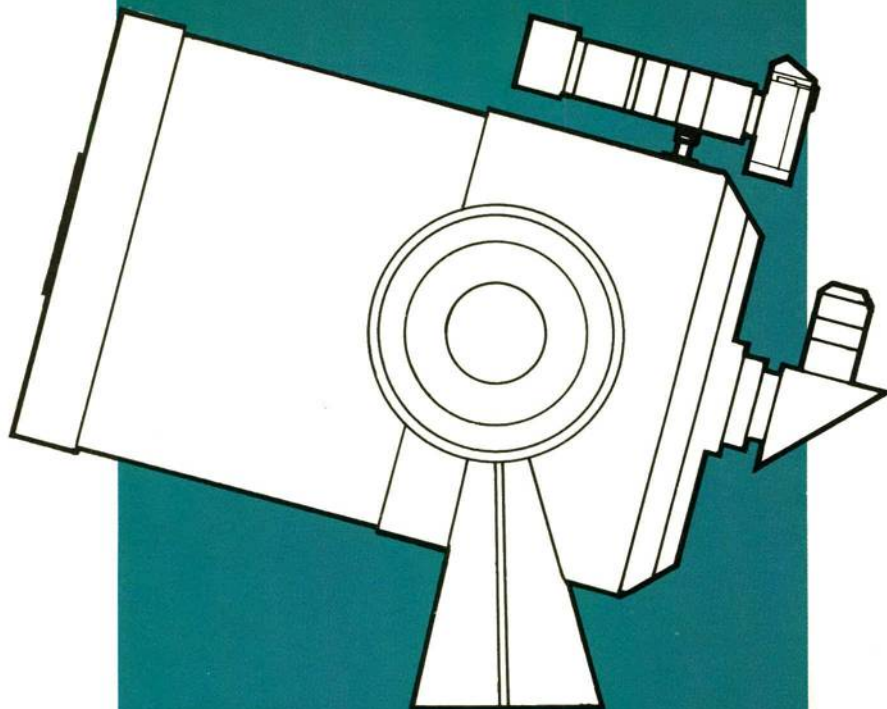
Now let's investigate the other side of the question: How do we know whether our guiding is good enough?

The answer lies within the guiding eyepiece — specifically, right on the reticle. This reticle is often just a cross hair, but ideally it should be combined with some sort of area indicator. One highly recommended type is the "double cross hair," two sets of cross hairs slightly offset to form a small, square box in the center of the field. Other types can be used in a similar fashion, but for the remainder of our discussion we'll assume that this is what you have.

The crucial thing is how large the box is relative to the allowable guiding error. A simple way of finding the box size, or line-pair separation, is to check the manufacturer's specifications. Lacking this data you can determine the size by making use of the fact that stars near the celestial equator cross the sky at very close to 15 minutes of arc per minute of time. With a stationary telescope you can time the "transit" of a star near the celestial equator across the guide box. The apparent angular size of the guide box against the sky for the particular objective in use is then simply this time multiplied by the angular rate of the star.



The photograph of the Orion Nebula (top) was taken by David Healy with a 14-inch $f/5.5$ Schmidt-Cassegrain telescope using Fujichrome 100 and a 31-minute exposure. Even a good photo like this, however, shows minor imperfections when enlarged. Blowing up the boxed region by $5\frac{1}{2}$ times, the bottom photo reveals elongated star images.



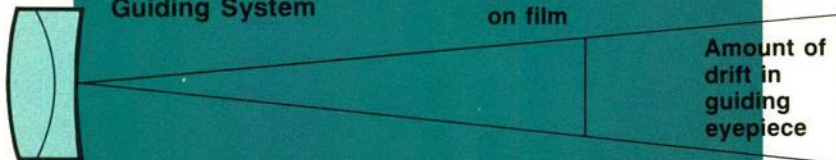
The simplest method of astrophotography is the piggyback technique. Superbly guided photos are easy to take when a relatively long focal length telescope guides a camera and lens combination mounted on top.

Photographic System



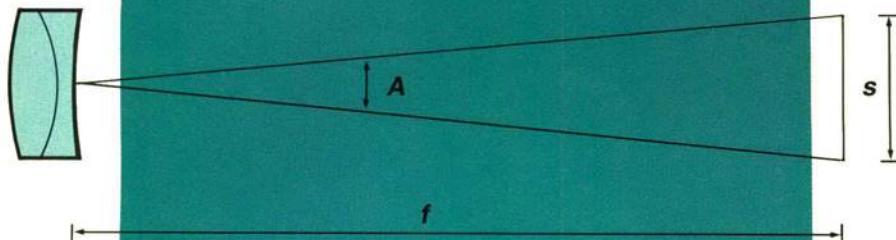
Amount of drift on film

Guiding System



Amount of drift in guiding eyepiece

Increasing the ratio of guiding focal length to photographic focal length gives you a greater guiding "leverage." Since this makes tracking errors easier to spot, and therefore to correct, it determines how sharp the resulting image will be. Seen here is a guiding focal length $1\frac{1}{2}$ times the photographic, which means the drift in the guiding eyepiece is 50 percent greater than that produced on film.



The size of an image on film (s) is related to its angular size (A) in degrees, and the focal length of the photographic system (f) by the formula $s \approx A \times f \div 57.3$.

However, knowing the actual reticle size will allow you to determine its apparent angular size when used with any given objective. This is accomplished by using the following formula for trail length:

$$d \approx f \times t \div 13,750$$

where t is the transit time in seconds, f the objective focal length, and trail length d is the box size in the same units as f (generally millimeters). Since most box sizes tend to be quite close to .2 millimeters, we'll use that value for the rest of our investigation.

Once the box size of the actual reticle is known, we can determine its apparent angular size on the sky, A , by using the inverted image size formula

$$A \approx 57.3 \times s \div f$$

where s is now the box size and f the focal length of the guiding objective. Here, too, we can simplify by using the assumed box size of .2 millimeters, giving:

$$A \approx 11.46 \div f \text{ (in degrees)}$$

$$\approx 41,250 \div f \text{ (in arcseconds)}$$

For a few common guiding focal lengths, here are the amounts of sky, in arcseconds, that such a box size corresponds to:

Focal Length	Arcseconds
900	46
1200	34
2000	21
3000	14

Clearly, a longer-focus guiding objective will reduce the amount of sky it shows, spreading a smaller amount of sky over the guide box. At the same time it will magnify small amounts of drift and thus make them more obvious.

Let's take a closer look at what this means. Note that the focal length of the guiding eyepiece has no effect on this discussion. A telescope eyepiece is merely a magnifying glass with which we examine the image produced by the objective. A guiding eyepiece is no different, except that it also lets us examine the reticle along with the image. Since changing eyepiece power (i.e., eyepiece focal length) affects image and reticle alike, it cannot have any effect on the relative sizes of the image and reticle. Thus, although a shorter eyepiece focal length might help us see both reticle and sky a bit better, only a longer objective focal length will magnify the sky relative to the guide box. Although either change will increase guidescope magnification, doing it by increasing the objective focal length tends to be more effective. This is one reason why guiding eyepieces tend to be more or less standardized at about 12.5mm focal length.

What we're after is a way to monitor our guiding efforts by relating the drift we see in the guidescope to the drift that we're producing on film. In other words, will the guiding be good enough if the guide star remains within the guide box at all times?

What we are seeking is the amount of

acceptable tracking error, T , as a multiple of the guide box size. The formula for this guiding tolerance will involve five quantities, including the photographic focal length and the guiding focal length. In order to differentiate between these two values, we shall switch to g for guiding focal length and reserve f for the photographic focal length.

Thus, the five key quantities are T , the guiding tolerance as a multiple of guide box size; d , the amount of acceptable image drift; b , the guide box size; g , the guiding focal length; and f , the photographic focal length. The formula is simply:

$$T \approx (d \div b) \times (g \div f)$$

If we continue with an assumed image drift tolerance of .04 millimeters and a guide box size of .2 millimeters, then the formula simplifies to:

$$T = .2 \times g \div f$$

a surprisingly simple expression involving nothing more than the relationship between the two key focal lengths.

This, of course, tells you how precisely you must guide. For example, whenever guide and photo focal lengths are equal — whatever they may be — the guide star must be confined to an area with sides equal to one-fifth of the guide box size.

Should you be fortunate enough to be able to select from among a range of focal lengths, then you might prefer the equivalent form:

$$g \approx (b \div d) \times T \times f$$

which, on substituting .2 millimeters for b and .04 millimeters for d , becomes:

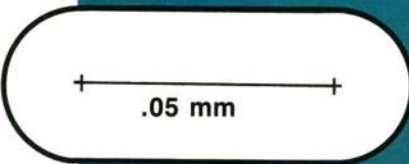
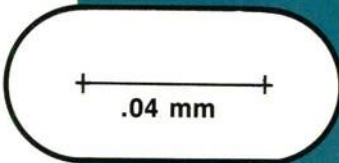
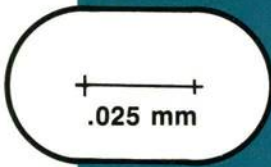
$$g \approx 5 \times T \times f$$

For example, if you want to let the guide star wander over an area that is one-third the box size on each side ($T = 1/3$), then this formula says that you need $g = (5 \div 3) \times f$. If you want things even easier, say $T = 1/2$, to let your guide star wander with impunity over an area that is one-half the box size on each side, then you need $g = (5 \div 2) \times f$.

Is it realistic to select from among a range of focal lengths? Quite possibly. Let's consider a Schmidt-Cassegrain telescope with a 2000mm focal length. With an off-axis guider and a 12.5mm eyepiece, we have equal guiding and photographic focal lengths — 2000mm — and a guiding magnification of $2000 \div 12.5 = 160\times$, which is $f \div 12.5$.

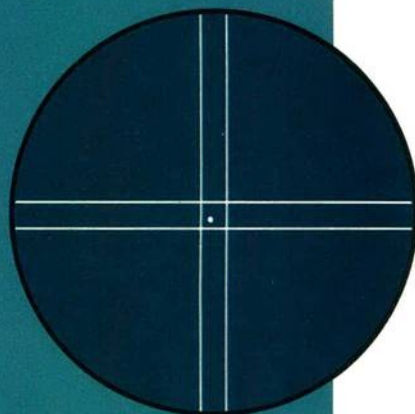
These are the minimum values for acceptable guiding. We can improve the situation by adding a focal reducer, such as the .6x example mentioned earlier. This leaves the 2000mm guiding focal length — and 160x guiding magnification — unchanged and cuts the photographic focal length to 1200mm. Now we have a guiding focal length equal to $(5 \div 3) \times f$ and a guiding magnification of $f \div 7.5$.

But let's go even further. Suppose we put a Barlow lens with a magnifying



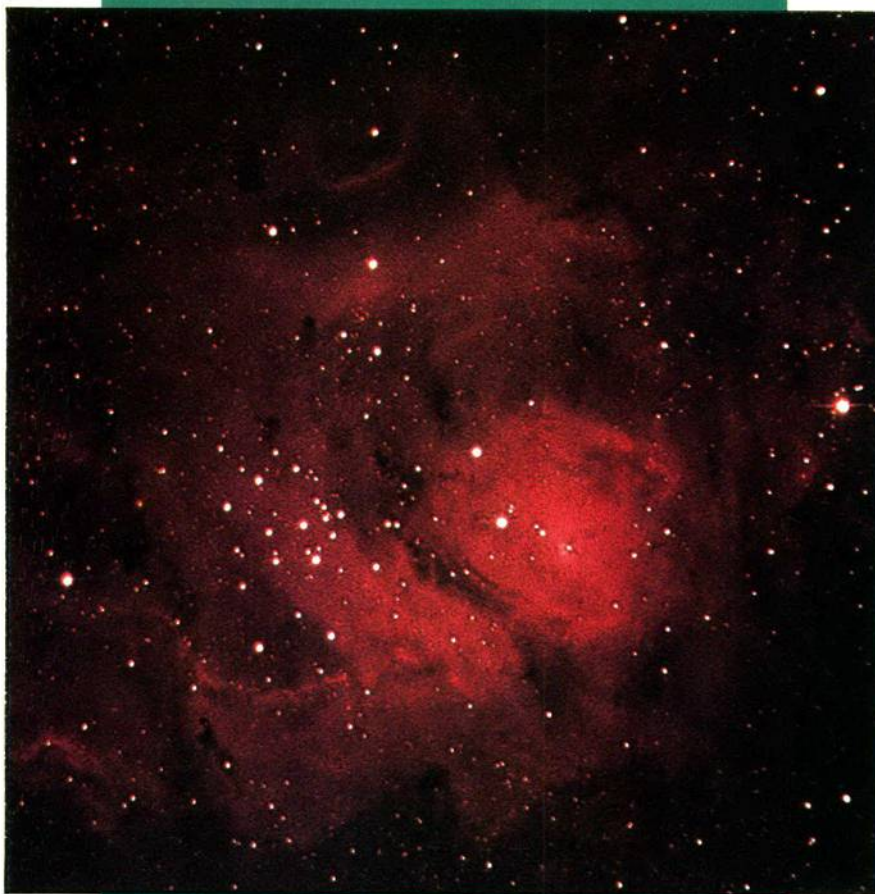
The amount an image drifts on the photographic emulsion determines whether any guiding error will be visible on the final negative. A drift of .04 millimeters is tolerable in most cases, but if the drift increases to just .05 the image will be noticeably trailed. With a drift of .025 millimeters star images appear almost perfectly round.

The most convenient type of reticle for guided astrophotography is the double cross hair. Constraining a guide star to remain inside the guide box formed by the intersection of the cross hairs, or within a certain fraction of it, is the objective.



Guiding Tolerance, in Box-Size Units, for .04 mm Image Tolerance, with .2 mm Reticle Box Size

Photo Focal Length mm	Image Drift of .04 mm arcsec	Guiding Focal Length in mm, and Apparent Size of .2 mm Reticle Box in arcsec			
		900	1200	2000	3000
		46	34	21	14
50	165	3.6	4.8	8	12
135	61	1.3	1.8	3	4.4
200	41	.9	1.2	2	3
300	28	.6	.8	1.3	2
400	21	.45	.6	1	1.5
500	17	.36	.48	.8	1.2
750	11	.24	.32	.53	.8
1000	8	.18	.24	.4	.6
1500	6	.12	.16	.27	.4
2000	4	.09	.12	.2	.3
3000	3	.06	.08	.13	.2



This is about as well as a photograph can be guided — the star images appear round even when extremely enlarged. Roger Sliva took this photo of the Lagoon Nebula with a 12.5-inch f/5 Newtonian telescope, Fuji 400 film, and a 20-minute exposure.

GUIDING RELATIONSHIPS

There are three different but absolutely equivalent ways of looking at guiding magnification, each of them nothing more than a ratio between two numbers. With the following assumptions:

Eyepiece Focal Length, $e = 12.5$ mm

Guide Box Size, $b = .2$ mm

Maximum Acceptable Image Drift, $d = .04$ mm

The values of the ratios needed for the level of guiding accuracy you want are:

	Minimum	Better	Optimum
Focal length to guiding magnification: $f \div m$	12.5	7.5	5
Guiding to Photographic Focal Length: $g \div f$	1	1.7	2.5
Guide Star Drift to Guide Box Size: $T \div b$	.2	.3	.5

power of 1.5x just ahead of the guiding eyepiece. Now the photographic focal length remains at 1200mm and the guiding focal length goes up to 3000mm, and we have a very desirable guiding focal length equal to $2.5 \times f$ and a guiding magnification, now 240x, equal to $f \div 5$.

The table titled "Guiding Tolerance" gives guiding tolerance values, T , for a variety of guiding and photographic focal lengths. For each focal length, it shows the amount of sky corresponding to an image drift of .04 millimeters (for photo) or to a guide box size of .2 millimeters (for guiding). For example, a 135mm telephoto lens produces .04 millimeters of image drift from a 61-arcsecond tracking lapse. A 900mm guiding focal length would show the guide star crossing the entire .2 millimeter guide box as a result of only a 46-arcsecond tracking error. The body of the table — the guiding tolerance values we've been after all along — are really the ratios of these amounts of sky.

If you guide a 400mm lens with a 2000mm guidescope you should be in fine shape by merely confining the guide star to the guide box, but letting it escape at all runs the risk of image degradation. There is even a bit more leeway — an area 1.2 box-sizes across — if you guide a 200mm lens with a 1200mm guidescope, or a 500mm lens with a 3000mm guidescope. This does not imply that these are equally easy to guide. The image drift at 500mm that results in degradation comes from far smaller tracking errors than at 200mm, calling for a delicate hand on the controls. However, the correspondingly larger guiding focal length will make those smaller tracking errors equally easy to spot. As you may expect, guiding gets easier with shorter photo focal lengths or with longer guiding focal lengths.

The guiding tolerance table is divided into three parts as a reminder that:

- a guiding tolerance of one-half the box size or better makes guiding quite comfortable;
- a guiding tolerance of one-third the box size is eminently practical;
- a guiding tolerance of one-fifth the box size is within the realm of the possible;
- a smaller guiding tolerance should not be considered by rational people.

Is this purely arbitrary? Not really; it's based upon experience. You can verify it by working through the algebra or a few numerical examples, but it happens that, for a 12.5mm guiding eyepiece, a guiding tolerance of .2 box-sizes corresponds precisely to a guiding magnification of $f \div 12.5$, and a tolerance of .5 box-sizes is exactly equivalent to a guiding magnification of $f \div 5$. Which is just about where all this started.

Barry Gordon is the author of *Astrophotography* (Gordon, 1983), from which this article is adapted. His last article for *ASTRONOMY* was "Much Ado About 0.1mm," which appeared in June 1985.



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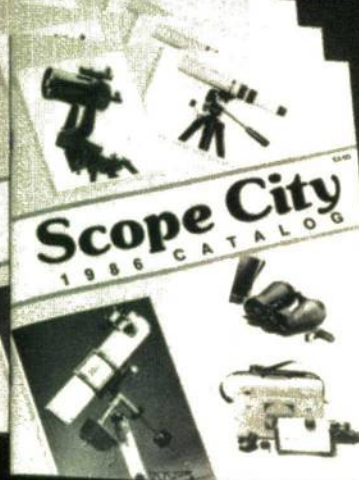


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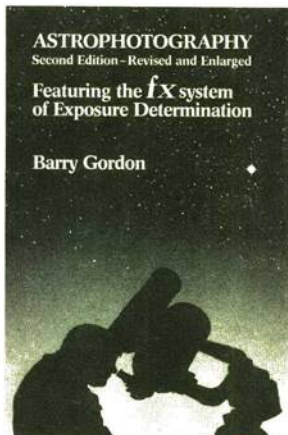
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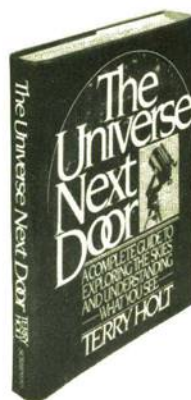
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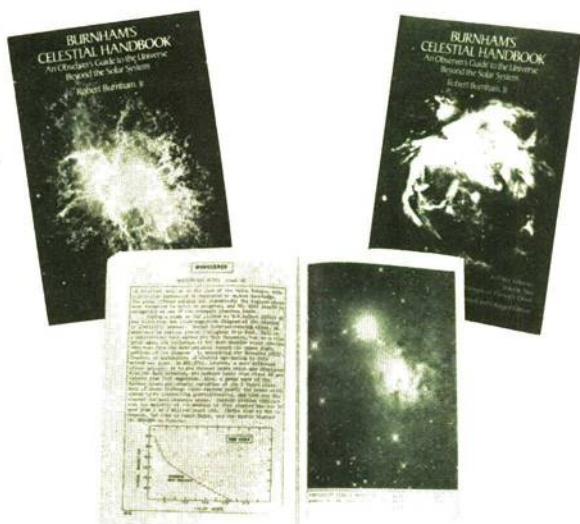


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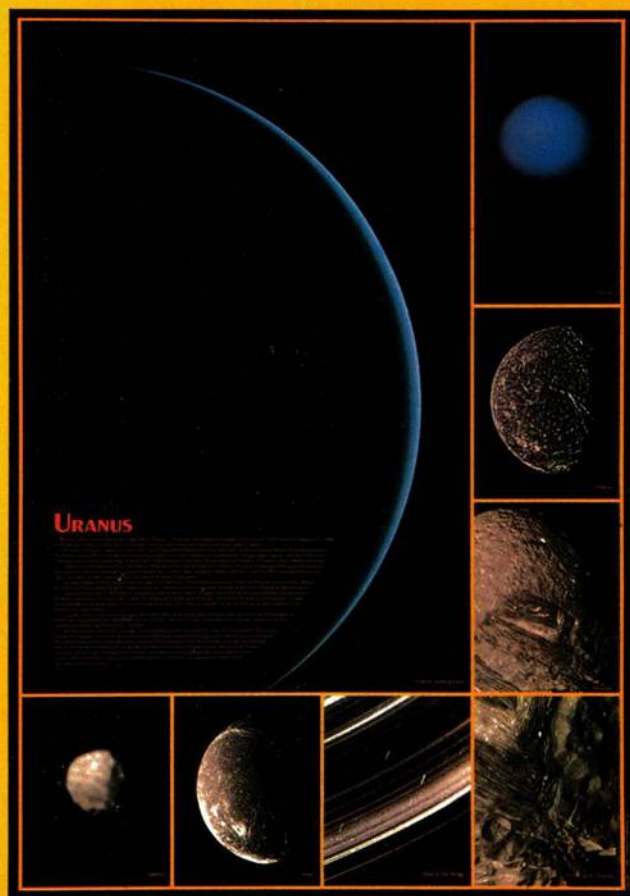
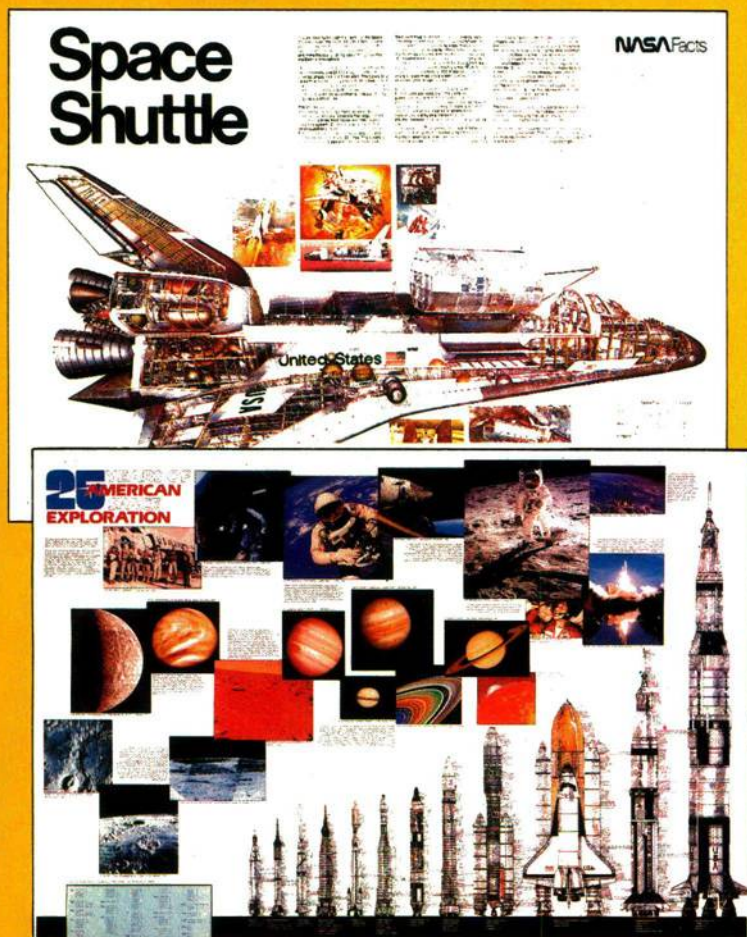
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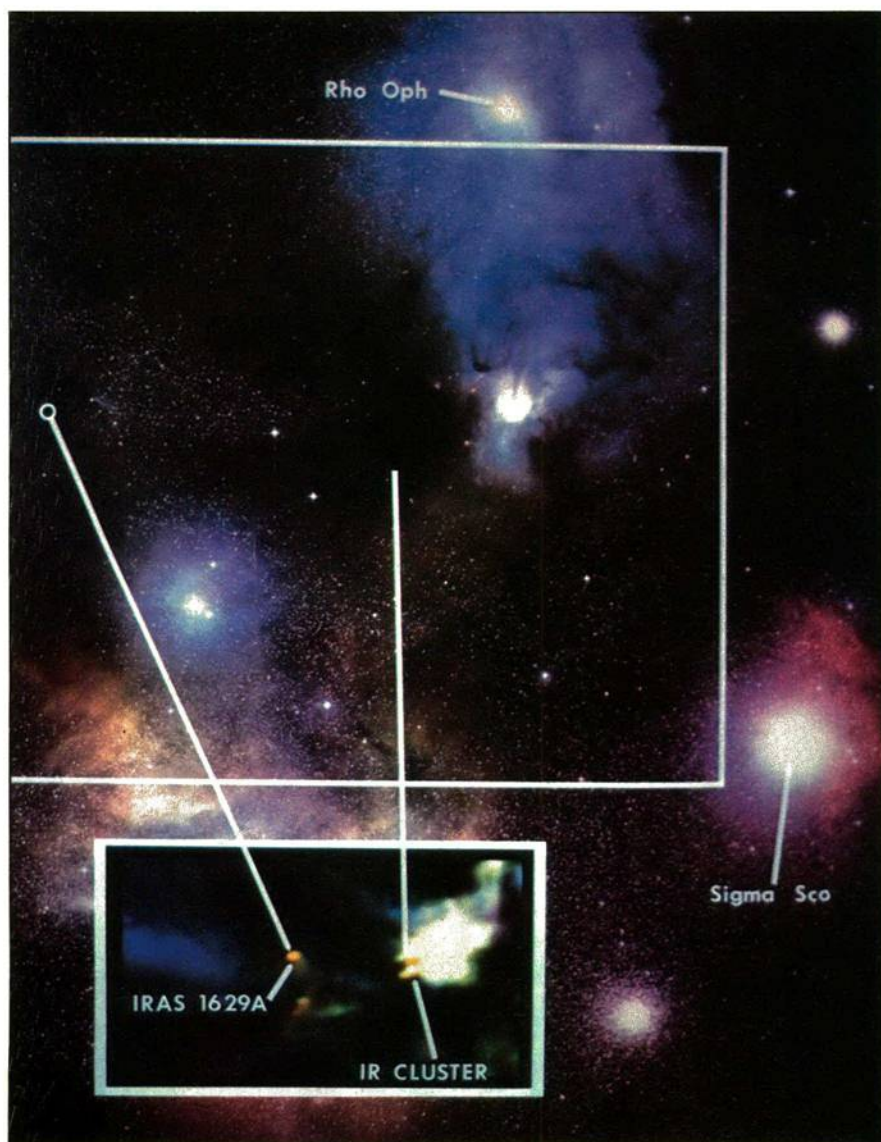
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The first direct evidence for the birth of a star comes from the infrared source known as IRAS 16293-2422. Dark clouds of interstellar gas and dust surrounding Rho Ophiuchi are visible in the center of the photo above from the Anglo-Australian Observatory and Photolabs, Royal Observatory, Edinburgh. The inset is a false-color image of the same region observed with the Infrared Astronomical Satellite, showing an infrared stellar cluster and the developing star, labeled IRAS 1629A. IRAS Infrared Processing and Analysis Center image.

Star Formation Process Observed For First Time

The first direct observations of a star in the process of forming have been made by University of Arizona astronomers Charles Lada, Philip Maloney, Christopher Walker, and Erick Young, and colleague Bruce Wilking of the University of Missouri at St. Louis. The researchers detected the collapse of part of an interstellar cloud of gas and dust around what is apparently an embryonic stellar core.

Astronomers have known for many years that stars form in interstellar clouds of gas and dust. Although it has long been suspected that this process occurs when a cloud fragment gravitationally collapses under its own weight, no instances had ever been directly observed. This lack of examples is partially attributable to the surrounding dust cloud, which blocks visible radiation.

To penetrate the interstellar dust the astronomers used the 12-meter radio telescope of the National Radio Astronomy Observatory on Kitt Peak, which was tuned to the microwave transmissions of carbon monosulfide gas. Based on their observations of Doppler-shifted emissions, the researchers believe that the region is falling in on itself.

The embryonic star was initially uncovered during an infrared sky survey by the Infrared Astronomical Satellite. Such objects glow in the infrared as gravitational energy released by the collapsing cloud is converted into heat. Designated IRAS 16293-2422, it lies imbedded in an interstellar cloud about 160 parsecs from Earth in the constellation Ophiuchus.

The collapsing portion of the cloud is approximately 650 billion kilometers in diameter, slightly more than one-tenth the size of the overall cloud, and contains roughly one-tenth the mass of the Sun. The core of the newly forming star is currently about one-quarter the mass of the Sun. These masses should increase as gravity draws material from the collapsing cloud

into the core and as more of the interstellar cloud participates in the overall collapse.

The star is at an extremely early stage of development, with an estimated age of 30,000 years. In another 100,000 years the embryonic core will have accumulated as much mass as the Sun, by which time the collapse is expected to stop. The new star will then begin to derive energy from nuclear fusion and emerge from the cloud as a visible object.

New Class of Supernovae Confirmed

Evidence for a unique class of supernovae was presented at the June meeting of the American Astronomical Society in Ames, Iowa. J. Craig Wheeler of the University of Texas at Austin reported that this research establishes a second category of "hydrogen-deficient Type I supernovae."

Observationally, supernovae fall into two categories. Type I supernovae do not show any hydrogen in their spectra. The progenitor star is thought to be a white dwarf in a binary system that accretes mass from a larger companion until it exceeds its limiting mass (the Chandrasekhar limit) and explodes. After the explosion, the light from the supernova drops off due to the radioactive decay of elements created by the incineration. Type II supernovae exhibit hydrogen lines in their spectra, implying that their progenitor stars are supergiants, stars larger than 8 solar masses.

Analysis of spectra of three supernovae — 1983n, 1984l, and 1985f — show no evidence of hydrogen but do exhibit helium absorption lines near maximum brightness and oxygen lines a few weeks after peaking. This, Wheeler says, indicates that this type of supernova is derived from a massive star that, after reaching the red giant stage, loses its hydrogen envelope, perhaps due to the gravitational influence of a companion star. Then, like other massive stars, it ultimately forms a dense iron core that collapses, generating the explosion. Such a supernova would lack hydrogen but would exhibit heavier elements in its spectrum.

Earlier this year Wheeler and Martin Gaskell of Ohio State University discovered the presence of oxygen in the spectra of supernova 1983n in the nearby spiral galaxy M-83. This finding is significant, Wheeler says, because the observations of 1983n were made after maximum brightness when the ejected gas was thinning out and exposing sub-layers of gas composed of heavier elements. This phase has been dubbed the "supernuclear phase" by Wheeler. Supporting Wheeler's and Gaskell's analysis is the spectrum of supernova 1985f in the spiral galaxy NGC-4618, which was found to be identical to 1983n according to astronomers at the California Institute of Technology.

Why Clavé eyepieces let you see stars 1/2 magnitude fainter with your telescope

Out here in the Northwest, we don't pretend to know much about advertising, and maybe we're foolish spending a small fortune for this space; but we got an idea the other day and we believe you folks who read Astronomy are the kind of folks who'd like to know about it. So here's our story:

Amateurs here in the Northwest take their observing seriously. It rains a lot and because there are few clear nights, we always look for ways to make the most of them.

So one night, we tried Clavé eyepieces from France. And all of a sudden, we saw stars 1/2 magnitude fainter through our own telescopes—"invisible" stars we had never seen before! Well, this sure surprised us (it was as if we suddenly had scopes 2" larger) and we just had to find out why only Clavé eyepieces do this.

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Precisely parfocal, not approximately

The Clavé's optical system is so carefully designed, it has no field curvature, spherical or chromatic aberration. You won't see any color around the moon's edge. Clavé mounts the optics in stainless steel barrels. Because, unlike other metals, stainless steel doesn't need extra treatments that deform mounting parts and destroy accuracy. For example, each and every Clavé's apparent field is exactly 48°. It doesn't vary. It's always 48°, not 46° or 47° or 51°. And the 48° field matches your eye's optimal field of view, so you always see an extraordinarily sharp and contrasty image.

The stainless steel barrel is machined to an accuracy of 3/10,000 of an inch to make Clavé eyepieces precisely parfocal, not approximately. Another important fact we learned: Clavé multicooates every lens of the eyepiece. This means each lens surface is individually multicooated—not just the top eyelens that looks attractive in many color advertisements. So you see whiter stars against a blacker sky background without any ghost images.

From all this, it was easy to understand the Clavé's incredible accuracy and diffraction limited optics let you see stars 1/2 magnitude fainter with your telescope. And do you know where we found Clavé eyepieces are used and continue to be used?

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kick out of knowing we also use these very same (and prestigious) eyepieces in our own amateur telescopes.

Not for professional astronomers only

But we're getting away from our story. The idea that kept coming to us was this: Why must only professional astronomers use Clavé eyepieces? Aren't there amateurs right here in America who would appreciate seeing stars 1/2 magnitude fainter with their telescopes just as much as professionals? It would be just like getting the bigger telescope we always dream of. Wouldn't amateurs like you and me like to give Clavé eyepieces to our special friends at Christmas?

So we made an experiment. We packed a few Clavés and took them down to some friends' favourite observing sites. You should have seen their faces when they took their first peek through a Clavé. They didn't know such eyepieces existed anywhere. They tried the

Clavés in their refractors and Schmidt-Cassegrains, reflectors and Dobsonians. And each time they were amazed at how much more they saw and the difference the Clavé's 1/2 magnitude gain makes. And when they turned to the planets, they gasped at the contrast and detail they saw. It was a night of excited observing.

Well, one observer wanted not only 4 for his C-8, but 3 more to send to his friends for Christmas. A second wanted to replace his 2 favourite (and expensive) eyepieces and another asked for 5 for the same purpose.

And that's how we got the idea that there must be enough discriminating amateur astronomers right here in the U.S.A. who'd like to own and use Clavés. And get the maximum performance and enjoyment from their fine telescopes.

So we talked it over the other night and said, "Let's offer Clavé eyepieces at a price everyone can afford—and see." We got a shock when we found what it would cost us to do it, but here we are—and you are going to be the judge.

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The information gained from studying Type Ib supernovae will likely help astronomers learn more about the interiors and physical properties of Type II supernovae, whose cores are usually obscured in a hydrogen envelope.

Details of the Type Ib supernovae can be found in the July 15, 1986, issue of the *Astrophysical Journal's* Letters to the Editor supplement. In addition to Wheeler and Gaskell, the research was conducted by E. Cappellaro, Harriet L. Dinerstein, Donald R. Garnett, and R. P. Harkness, all of the University of Texas.

Deciphering "Variable A" in M-33

In 1953 Edwin Hubble and Allan Sandage discovered a new group of bright blue variable stars in the nearby spiral galaxies M-31 and M-33. Others were subsequently discovered in NGC-2403, M-81, and M-87. The star S Doradus in the Large Magellanic Cloud is also considered to be of this class. This group of stars has come to be known as Hubble-Sandage variables. Generally, their colors, luminosities, and line spectra indicate that they are F-type supergiants of about 60 solar masses, still young, but unable to evolve normally because of their huge mass.

However, spectral analysis presented at the June 1986 meeting of the American Astronomical Society by Roberta Humphreys, Terry Jones, and Robert Gehrz of the University of Minnesota has shown that one of the original Hubble-Sandage stars in M-33, designated Variable A, poses a conundrum.

In 1951 Variable A was one of the most luminous stars in M-33. Spectra of the star made at that time indicated that it was an F-type supergiant. Then, after showing a steady increase in brightness since 1900, Variable A rapidly declined by four magnitudes and changed in color from yellow to red over a period of a month in late 1951. It brightened briefly once in 1952, but quickly fell again to minimum brightness.

A recent spectrum revealed strong titanium oxide bands, the tell-tale characteristic of cooler M-type stars similar to Betelgeuse and Antares. Moreover, infrared photometry showed that Variable A was emitting strong infrared radiation, which the science team speculates may be due to a surrounding dust shell.

What is Variable A? Is it an F-type supergiant or an evolving M-type supergiant or is it something else? In trying to understand this quizzical star, Humphreys, Jones, and Gehrz looked for similarities with other stars. They found that, although Variable A's spectral fluctuation is similar to the cooler supergiants like Rho (ρ) Cassiopeiae (which ranges from spectral type F8 to M5 with brightness changes), some of its characteristics are also similar to a group of variables

known as "luminous blue variables" (LBVs). These are unstable, highly luminous stars that, during maximum brightness, rapidly eject shells of gas resembling the cooler photospheres of A- and even F-type supergiants. (The photosphere of a star is the surface from which nearly all of the energy emitted by the star is radiated into space.) These stars also exhibit some of the same weak lines of hydrogen as those found in Variable A's spectrum during its maximum.

The scientists speculate that Variable A is blowing off mass at a slower-than-normal rate for LBVs, perhaps due to a denser atmosphere. If the star's behavior can be related to LBVs, then they suggest that Variable A may be evolving into a Wolf-Rayet star, a type of hot, luminous star with exceptionally high stellar winds that continuously blow off shells of gas. However, considerably more data is needed to confirm this. Additional infrared observations to determine the star's total energy distribution are planned for the near future.

"Variable A is a very massive evolved star, one that is approaching the final stages of its life," Humphreys says. "However, we do not know in which direction it is going now. Is the surface temperature cooling off or heating up? In either case, it is having a hard time doing it."

Survey for Faint Galaxies Proposed

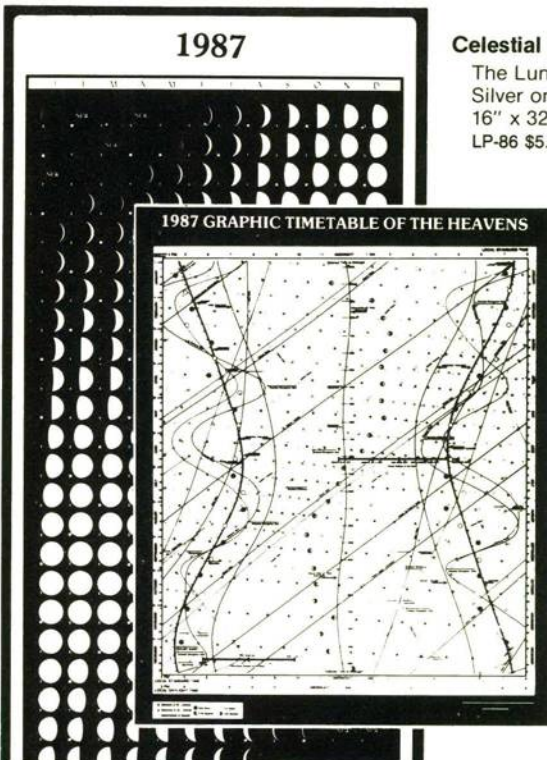
Astronomers of the National Optical Astronomy Observatories (NOAO) have proposed a deep-sky survey that would permit the first detailed spectroscopic study of galaxies as faint as 27th magnitude. The concept, presented by NOAO astronomers Jacques Beckers, Roger Davies, and Patrick Seitzer, would also allow astronomers to view an epoch in the universe 10 to 12 billion years ago, when galaxies were just forming. The proposal was made at the June 1986 meeting of the American Astronomical Society held in Ames, Iowa.

According to Beckers, who directs NOAO's Advanced Development Program, the project, called the Deep Polar Spectroscopic Survey, would use a 4-meter telescope designed to point continuously at the north or south celestial pole. The telescope, located at either Kitt Peak or Sacramento Peak in the Northern Hemisphere, or Cerro Tololo in the Southern Hemisphere, would reach 27th-magnitude objects by making exposures of 1,000 to 2,000 hours of dark time, which would require one year of observations. These long exposures would give astronomers enough photons to analyze spectroscopically to determine the galaxies' star populations, ages, chemical compositions, and other properties.

"At magnitude 20 to 21," Beckers explains, "you're basically seeing everything there is to be seen in our

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galaxy, and you're running out of stars. Fainter than magnitude 21, the number of stars decreases quickly, but the number of galaxies increases. When you go a hundred times fainter, which is what we are talking about, everything you see is galaxies. You are back near the time when the galaxies first began to form."

The pole-pointing telescope would be designed to rotate once per day, nullifying the effects of the Earth's rotation. During the day it would be used for continual testing of the Borosilicate mirror, a "spin-cast" mirror being developed for the primary of the NOAO's proposed 15-meter National New Technology Telescope. After a year or two of taking data, Beckers says, the telescope could be relocated to the other hemisphere or applied strictly to spectroscopic studies.

Roger Davies believes the spectra of faint galaxies obtained by the survey telescope should be quite good.

"We should be able to understand the kind of stars that made up the galaxies and what the galaxies were made of — the abundance of various elements," Davies says. "And we may do better than our current estimates indicate. Because the stars in galaxies were younger at earlier epochs, the galaxies themselves were more luminous. If we have underestimated how much their luminosity has faded over time, we may find young galaxies bright enough to be seen at yet higher redshifts."

Royal Greenwich Observatory To Relocate in 1990

The decision of the British Science and Engineering Research Council to move the venerable Royal Greenwich Observatory (RGO) has touched off a storm of controversy in the British astronomical community. The move from Herstmonceux Castle in Sussex to the Institute of Astronomy at the University of Cambridge is scheduled to take place in 1990. This will be the second move for the RGO, which abandoned the original Greenwich site in London shortly after World War II in a search for clearer skies.

The decision to move stems from the Council's desire that institutions under its control operate in support of British universities and polytechnics and not as independent research organizations. RGO astronomers currently spend only 10 percent of their time doing research with the other 90 percent going toward the management of research facilities for the academic community.

In addition to the perceived need for a closer university association, financial considerations also played a role in the decision. Optical astronomy has done relatively well in Britain during the past several years, but the future looks quite bleak. A 30-percent staff reduction is expected over the next five years, and

many government officials reportedly believe that the upkeep of the castle is too expensive.

Critics of the move argue that the RGO has already built a close working relationship with the nearby University of Sussex, one which will most likely be destroyed after the move takes place. There is also the added danger that the relocation will create greater difficulties in developing future relationships with universities other than Cambridge.

Financially, opponents of the move feel staff reductions are unwarranted and too severe. Particularly with the approaching completion of the 4.2-meter William Herschel telescope at La Palma in the Canary Islands, they feel that now is not the time to reduce staffing. The Council's desire to pay for the move and the necessary construction entirely from the proceeds of the sale of Herstmonceux Castle is another bone of contention, since no one has any idea how much the sale of the castle and grounds might raise.

When it was first announced that the RGO would be moving again, there were three sites in the running. The selection of Cambridge rather than the University of Manchester or a merger with the Royal Observatory at Edinburgh was a victory for the RGO astronomers, who vigorously fought the Council's other two proposals. Now opponents of the move hope to pressure government officials into overturning the decision and allowing the RGO to remain at Herstmonceux.

Amateurs to Observe with Hubble Space Telescope

NASA and the Space Telescope Science Institute have announced plans to allow amateur astronomers to make observations using the Hubble Space Telescope (HST) and to have access to HST data and image archives. In addition, special cooperative observing programs will allow amateurs to make useful contributions to the science of astronomy.

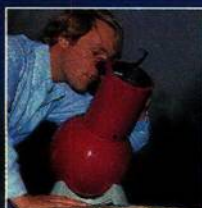
Since observing time on the HST is in great demand by professional astronomers, Dr. Riccardo Giacconi, director of the Space Telescope Science Institute in Baltimore, will make available observing time which has been set aside for astronomical "targets of opportunity."

In announcing the program, Dr. Giacconi said, "The professional astronomy community is deeply grateful to amateur astronomers for decades of assistance in our observational programs and for helping to interpret our findings to the public at large."

Representing amateur astronomers is a panel of representatives from IOTA, WAA, ISRG, AAVSO, IAPPP, ALPO, and the Astronomical League.

Specific plans for soliciting and evaluating proposals from amateur astronomers will be announced.

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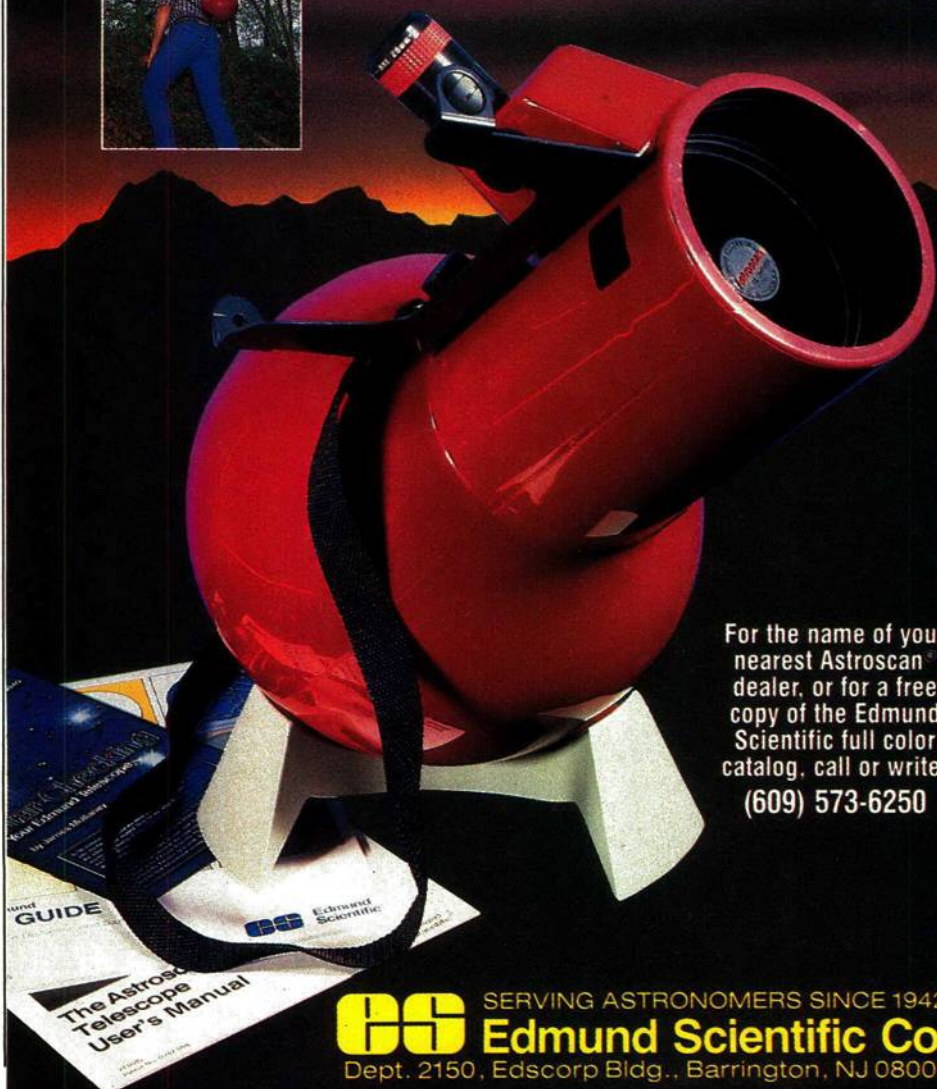


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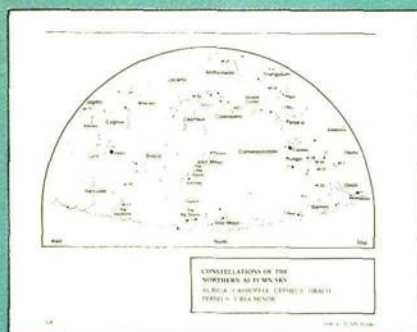
Guide to the Stars

Exploring the Sky

CHAPTER 14
The Moon

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THE NORTHERN ATLANTIC MEX AS SEEN ON:

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OCTOBER 15 AT 10 P.M.	DECEMBER 1 AT 7 P.M.

[illegible]

Table 4. (continued)

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On May 17, just two weeks after the discovery of a supernova in the bright galaxy NGC-5128, astronomers at Leuschner Observatory found a supernova (1986i) in the face-on spiral M-99 in Coma Berenices. The supernova is located just to the left of the galaxy's nucleus. The discovery was reported by a group led by C. Pennypacker. Glowing at 14th magnitude when discovered, the exploded star had faded to magnitude 15 by late June. R. Kirshner and I. Wilson at the Harvard-Smithsonian Center for Astrophysics reported that the supernova, based on their low-dispersion spectra, is a Type II object. Photo made on June 29 by Boutin Moreau.

ASTRONOMY AstroCalendar

October 2-5

Okie-Tex Star Party (sponsored by the Oklahoma City Astronomy Club), Lake Murray, Oklahoma. Contact: Joe Pearson, 700 Teal Place, Edmond, OK 73034.

October 4-5

AstroAssembly 1986 (sponsored by Skyscrapers, Inc.), Seagrave Memorial Observatory, North Scituate, Rhode Island. Contact: Brian Magaw, Town Farm Road, P.O. Box 325, Pascoag, RI 02859. Phone (401) 568-8424.

October 10-12

Pacific Planetarium Association Fall Meeting, Salem, Oregon. Contact: Tom McDonough, Chemeketa Community College, 4000 Lancaster Dr. NE, P.O. Box 14007, Salem, OR 97309. Phone (503) 399-5161.

October 16-18

Rocky Mountain/Great Plains Planetarium Associations Joint Meeting, McDonnell Star Theater, St. Louis, Missouri. Contact: Laura Kyro, St. Louis Science Center, 5050 Oakland Blvd., St. Louis, MO 63110. Phone (314) 289-4456.

October 17-19

Midwest Space Development Conference, Lorain, Ohio. Contact: Jim Wood, Conference Coordinator, 2720 West 40 Street, Lorain, OH 44053. Phone (216) 282-6329.

AstroCalendar notices must be submitted at least four months in advance of the date of the event.

When contacting organizations that are sponsoring events, enclose a self-addressed, stamped, legal-size envelope for their response.

October 24-26

8th Annual Astronomy Jamboree, Custer Institute, Southold, Long Island, New York. Contact: Tom Carey, Vanderbilt Planetarium, Centerport, NY 11721. Phone (516) 757-7502.

October 25

Telescope Users' Clinic, Whittier College, Whittier, California. Contact: Bob Ferguson, Western Observatory, 13215 E. Penn St., Suite 411, Whittier, CA 90602. Phone (818) 795-4181.

October 31-November 2

Deep South Regional Stargaze, Percy Quin State Park, McComb, Mississippi. Contact: Frank W. Loflin II, ALCOR, Jackson Astronomical Association, 280 W. Lorenz Blvd., Jackson, MS 39213. Phone (601) 982-2388 days or (601) 856-3636 evenings.

January 4-8, 1987

169th Meeting of the American Astronomical Society (professional meeting sponsored by Mount Wilson Observatory and Caltech), Pasadena, California. Contact: AAS, 1816 Jefferson Pl. NW, Washington, DC 20036.

February 12-14

Automatic Photoelectric Telescopes II (Fairborn IAPPP Symposium), Apache Junction, Arizona. Contact: Russell M. Genet, Fairborn Observatory, 1357 91st Pl., Mesa, AZ 85207.

March 14

Astrophoto VII (sponsored by Ventura Co. Astronomical Society and Orange Co. Astronomers), Moorpark College, Moorpark, California. Symposium on amateur astrophotography. 8 p.m. Contact: VCAS/Astrophoto VII, P.O. Box 982, Simi Valley, CA 93062.

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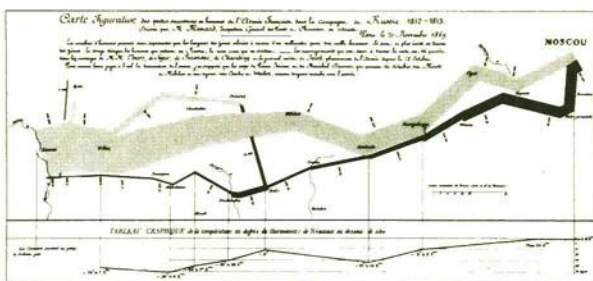
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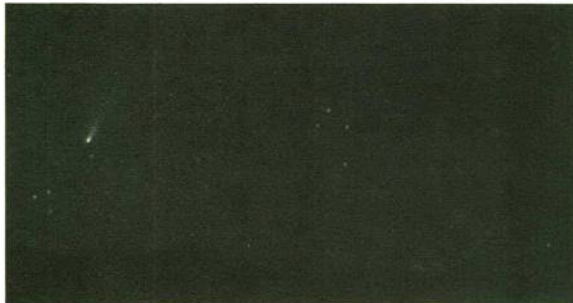
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Halley rises over Haleakala, Planet Earth's third highest mountain. Canon 4SB Rngldr, w/Nikkor 1/1.4 50mm, Fuji 1600, 20 secs. Guardrail mount, March 7, 1986, Island of Maui.



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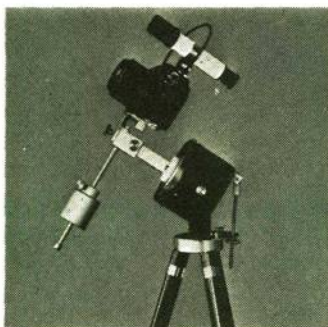
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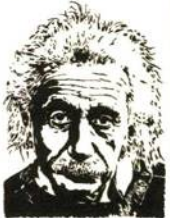
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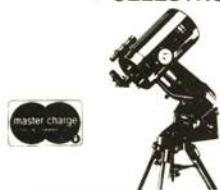
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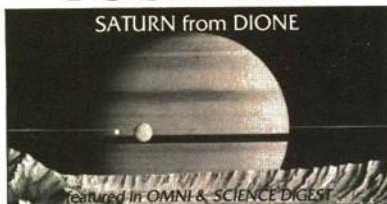
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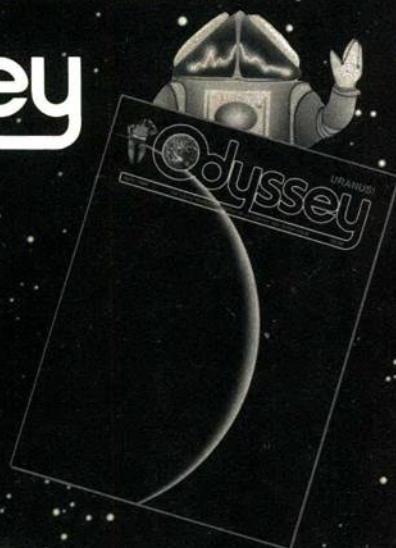
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Stellar Populations: Key to the Clusters

by Gail O. Clark

Among the most attractive objects in the night sky are star clusters, colonies of distant suns sparkling with a radiance that masks their complex and varied origins. Pleasing to the eye, rich in detail, and easily within reach of modest backyard telescopes, star clusters rank among the favorite objects of many sky watchers. And it's no wonder, since vivid examples of these intriguing objects are visible on any clear night of the year.

Superficially, the bright star clusters we see scattered along the Milky Way appear to be all alike. Many are irregular in shape and loose in structure, with member stars scattered throughout. These open, or galactic, clusters show a great range in the brilliance of their individual stars. Such apparently haphazard groupings seem to be without organization or design.

But other types of star clusters — globular clusters — are conspicuously different. Circular in outline, globular clusters appear to be constructed according to some cosmic blueprint designed to produce great spheres of glittering stars. These round conglomerations of suns, denser toward their centers, are composed of stars of nearly equal brightness.

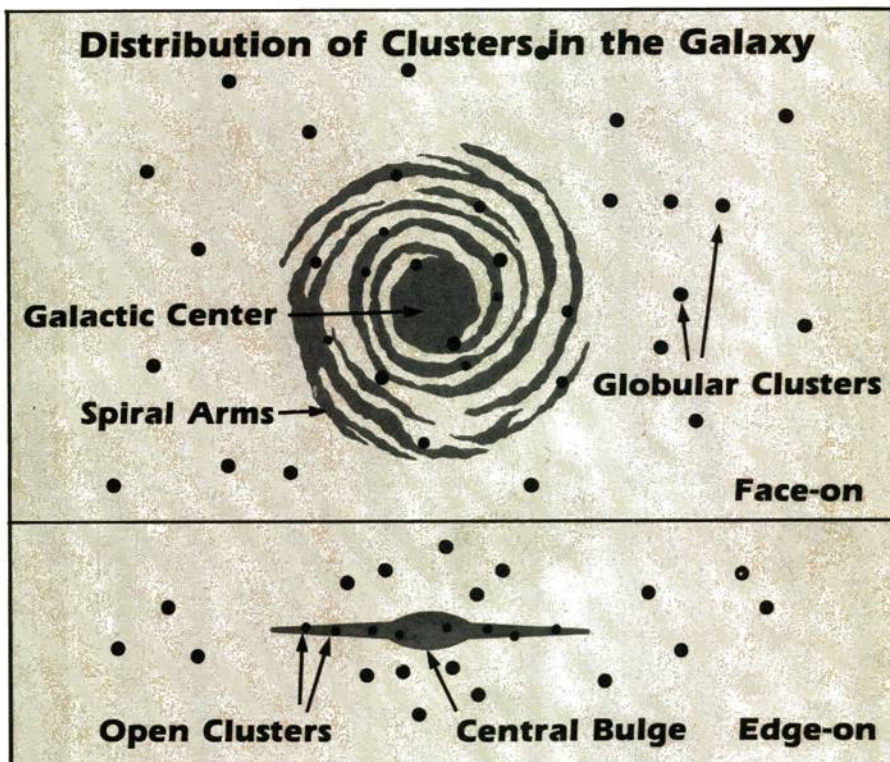
Each of these two types of star clusters has its own distinct characteristics that make it possible to tell which kind it is at a glance. But there are other, more profound differences between open and globular clusters that help explain the working of our galaxy and the way in which stars are born, evolve, and die.

The Recognition of Star Clusters

To explore how our understanding of clusters has grown we must step back to a time before the invention of the telescope. Here we encounter a world unaffected by light pollution where observational astronomy was limited by the eyes of the observer. At this time star clusters smaller and dimmer than just the very brightest were thought to be nebulae, as were all unresolvable smudges in the sky.

Later, astronomers such as Charles Messier and John Flamsteed recognized many of the fuzzy patches of light as clumps of stars, but they made no serious attempts to categorize them. Finally, in 1786, William Herschel developed a crude system for classifying star clusters. He placed them along a continuum beginning with "coarsely scattered clusters" and concluding with "very compressed and rich clusters."

Herschel clearly recognized the unique appearance of the symmetrical, apparently spherical star systems — he coined the term globular cluster — but he didn't attempt to classify clusters beyond their degree of richness or density. Nonetheless, it was a beginning.



In 1944 Walter Baade, applying the powerful tool of spectroscopy, originated a classification system for stars that led directly to a clear distinction between star clusters. He boldly suggested that all stars could be placed into one of two well-defined categories that he called Population I and Population II. Because the stars in clusters could be classified, the clusters themselves could be classed by the types of stars they contained.

Stellar Populations

Classic Population I stars are extremely young, hot, white or blue stars enriched with heavy elements. They are located in the spiral arms and nuclear bulge of our galaxy — regions experiencing active star formation — and are associated with gas and dust. These so-called "disk stars" exist in great numbers. New Population I stars are continually but slowly being formed from the remnants of stellar explosions and decay.

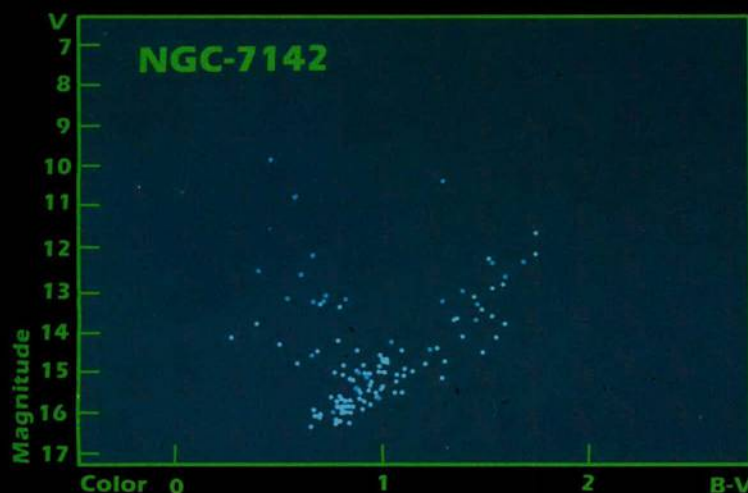
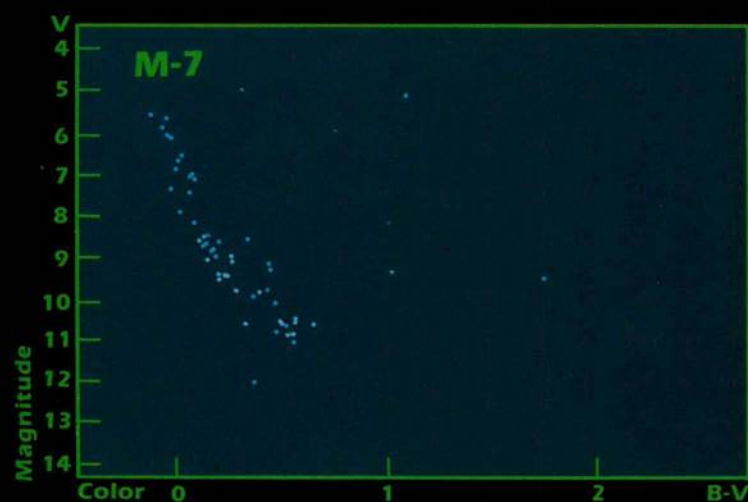
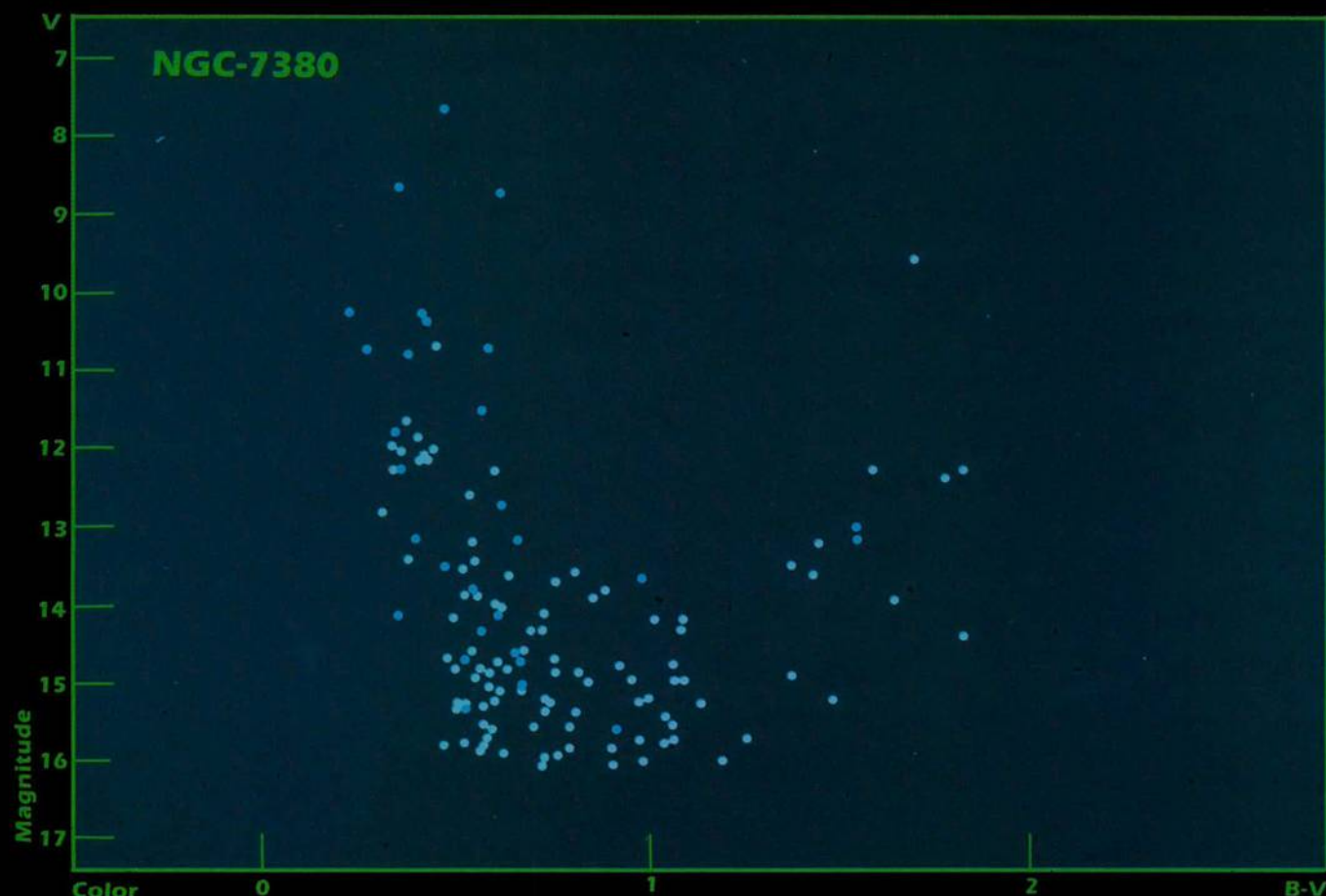
Population II stars are extremely old red or orange stars, which are nearly devoid of heavy elements. These old giant and supergiant stars are not residents of the galactic disk but of the extensive halo surrounding the Galaxy's nucleus.

More recently astronomers found that the stars in the Milky Way are a continuum of types between Population I and II. The technical classifications are:

- Extreme Population I, including interstellar gas and dust,

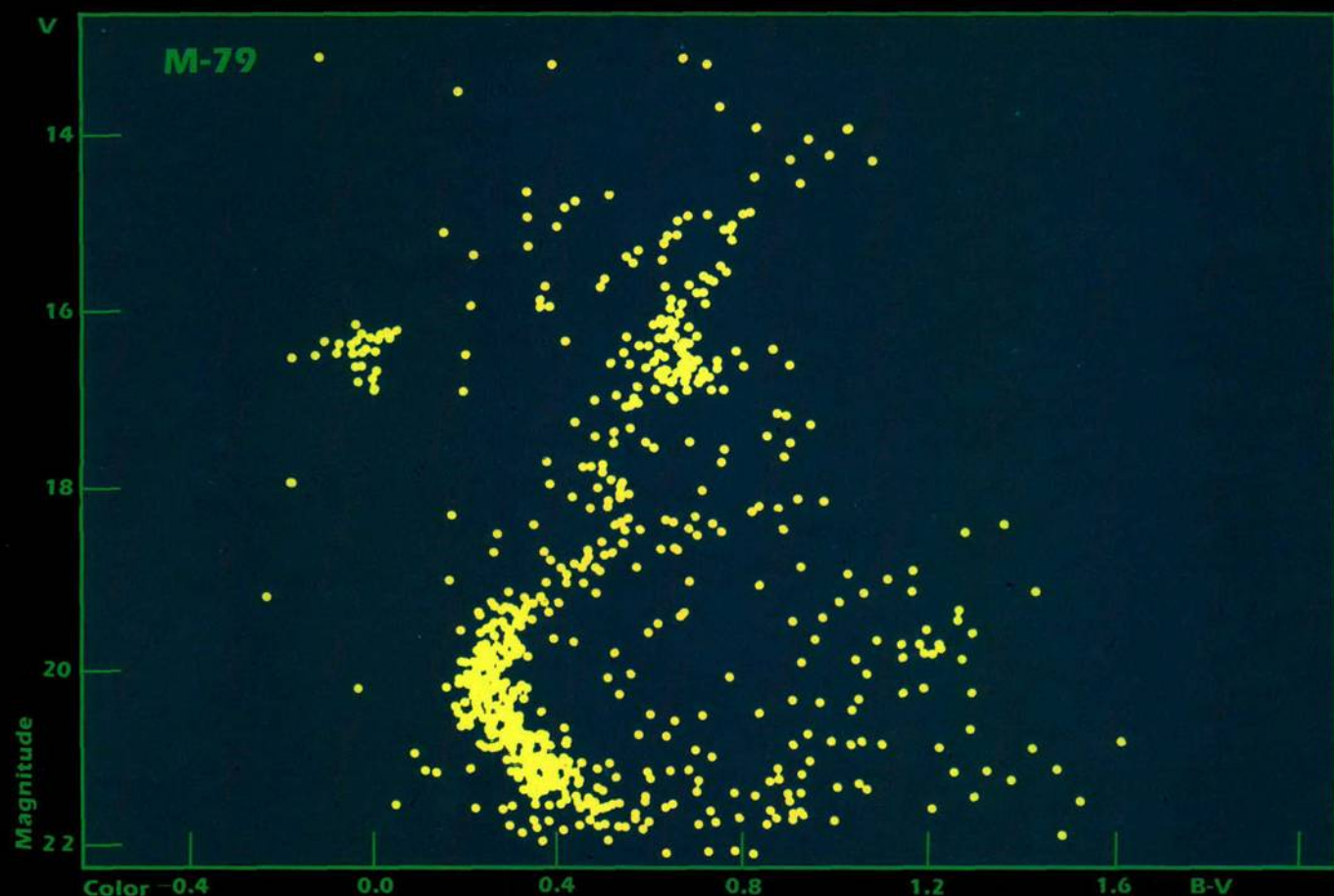
NGC-3293 in Carina is a typical open cluster lying in the plane of the Galaxy and is composed of young, hot stars. Anglo-Australian Telescope Board photo.





These color-magnitude diagrams for three open star clusters illustrate the changes stars — and the clusters as whole entities — undergo as they evolve. The graphs plot color (temperature) versus brightness for stars known to be members by proper motion and other studies. Photoelectric data are represented by blue; light blue represents photographic observations.

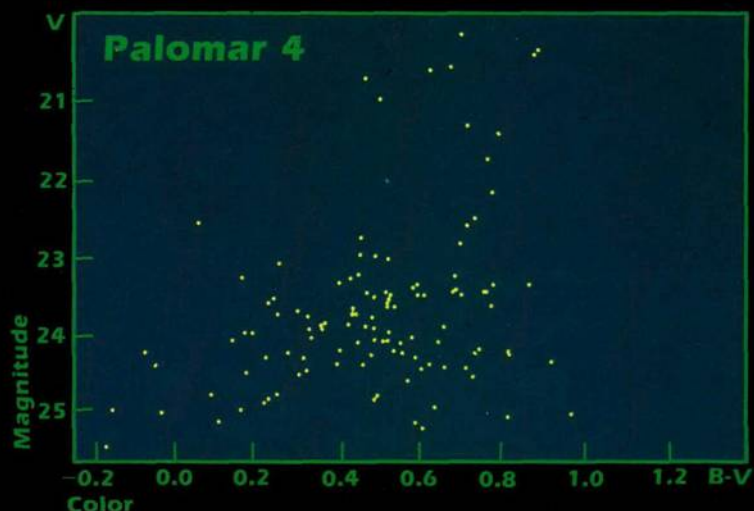
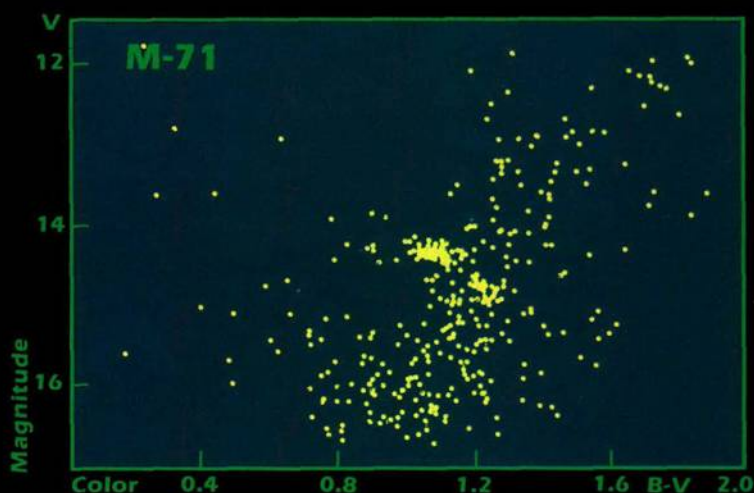
NGC-7380 in Cepheus (top) is a very young open cluster, some 3.8 million years old, and is still surrounded by a thick blanket of nebulosity. A high percentage of its stars lie toward the blue (left) end of the graph, similar to those of M-7 in Scorpius (200 million years, center). In an old open cluster like NGC-7142 in Cepheus (bottom), however, the stars are evolved toward the red end of the graph. NGC-7142 is some four billion years old. Diagrams courtesy Arthur Hoag, from U.S. Naval Observatory *Publications*.



Unlike open clusters, which form more or less continuously in the galactic disk, all globular clusters formed at about the same time in the early history of the Galaxy. To discover this, astronomers analyzed color-magnitude diagrams like the one at the top of M-79 in Lepus.

By fitting theoretical models against observed data made through telescopes, astronomers can estimate the age of a globular by looking at the main sequence — the clump of stars near the bottom — and the “turnoff point,” the area where the top of this clump curves toward the upper right, and then fitting this information to an evolutionary model of a cluster.

Less typical are the color-magnitude diagrams for M-71 in Sagitta (center) and the extremely faint globular Palomar 4 in Ursa Major (bottom). Diagrams after J.N. Heasley, Kenneth A. Janes, and Carol Christian (M-79), Kyle M. Cudworth (M-71), and B.C. Reed and W.E. Harris (Palomar 4).





Typical Properties of Clusters

Open Clusters		Globular Clusters
Galactic Disk	Location	Galactic Halo
Pop. I	Star Types	Halo Pop. II
<500	Membership	>100,000
<1 pc	Diameter	40 pc
1-4,000 Myr	Age	>10,000 Myr
O-B-A	Spectra	F-G

47 Tucanae is a typical globular cluster lying in the halo of the Galaxy and is composed of old, cool stars. Photo courtesy Cerro Tololo Interamerican Observatory.

HII regions, OB associations, massive blue supergiants, classic Cepheid variables, and young open clusters. These objects are extremely metal-rich and are distributed in clumps throughout the spiral arms; their orbits are roughly circular.

- Older Population I, including the Sun, A stars, Me dwarfs, giants, and old open clusters. These objects also orbit the galactic center in roughly circular paths.

- Disk Population, composed of stars in the galactic bulge, planetary nebulae, novae, and RR Lyrae stars. Unlike Population I objects, the disk population displays considerable concentration toward the galactic center and slightly eccentric orbits about it.

- Intermediate Population II, encompassing high-velocity stars and long-period variables, whose distribution is strongly concentrated toward the galactic center and whose orbits are eccentric.

- Halo Population II, including globular clusters, subdwarfs, long-period RR Lyrae stars, and Type II Cepheids. They are strongly concentrated toward the galactic center and have very eccentric orbits.

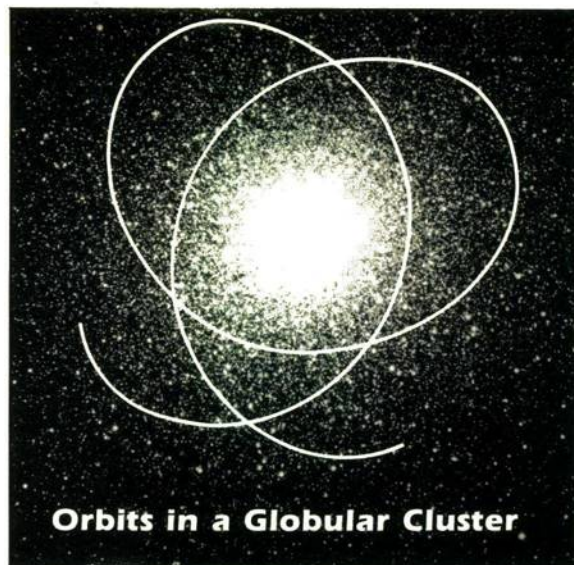
Open Clusters

The fiery Population I suns composing open clusters form at the same time that the cluster forms from a primordial cloud of cosmic gas and dust. These massive blue and white stars burn ferociously, depleting their stellar fuel at a hurried rate.

The gleaming members of an open cluster also share a common motion through space, zipping along at speeds of tens of kilometers per second as they revolve about the galactic center. But as inhabitants of the galactic disk, open clusters are subject to a variety of perturbing effects including tidal forces generated by the Galaxy's center, the cataclysmic outleash of a nearby supernova, the tug from a passing star, or the shearing tug of a spiral arm. Such influences eventually cause open clusters to disintegrate, their component stars drifting away to join the countless single, double, and multiple stars spread throughout the galactic disk.

Even with so many forces acting on open clusters, some retain small amounts of dust, gas, and debris left from their creation for millions of years. Gravitational dynamics can cause the debris to collapse into new stars, thereby creating a second wave of star formation within a cluster. The gossamer nebulousity within the Pleiades cluster is a classic example of material remaining after the main cluster has formed. Since the material amounts to several solar masses, there exists the possibility that additional Pleiades will form in the future.

If open clusters are youngsters — the Pleiades is only 78 million years old and the Hyades about 660 million — then globular clusters are grizzled ancients. For example, M-13, the



Hale Observatories

jewel-like cluster in Hercules, is between 12 and 14 billion years old, not much younger than the age of the universe.

Globular Clusters

Globular clusters have traveled distinctly different paths than their galactic counterparts. Condensing out of the primeval gas cloud from which the Galaxy formed, these glittering colonies occupy a vast, roughly spherical region surrounding the galactic nucleus. This abode of the globulars, the galactic halo, measures a staggering 50 kiloparsecs or more across.

These colossal balls of stars, containing up to one million aged suns, majestically orbit within the halo, arcing far out toward the lonely reaches of intergalactic space. Slowly they swing back, plunging through the galactic disk, and then move off again to wend their way once more along a highly eccentric orbit.

As a result of their eccentric orbits, globular clusters spend only a brief period of time within the galactic disk, thereby minimizing the disruptive conditions constantly plaguing open clusters. But globulars don't go totally unscathed. They tarry long enough in the disk to have dust and gas swept out of them routinely, assuring that new stars will not form and that they will eventually burn out.

Globulars are very stable objects; the massive clusters age slowly and gracefully, their component stars conservatively moving into deep old age. The ancient stars maintain such a low surface temperature and internal uniformity that their fuel becomes exhausted long before the parent cluster disintegrates.

Yet the stars in globulars are certainly not static. Each ponderously rotates on its own axis, simultaneously orbiting about the center of the cluster's mass in an elliptical path. Low-mass stars, orbiting faster than their heavier siblings, migrate toward the outer regions of the cluster. Heavy stars drift toward the cluster's crowded, chaotic nucleus. Such action results in a globular's core containing stars as near as 0.2 parsecs apart.

Most of the nearly 200 known globulars contain variable stars, distance indicators that have added much to the growing store of knowledge about these vast assemblages of ancient suns.

With all their differences and similarities, both types of star clusters are important laboratories for contemporary research. Globular clusters allow us to peer back into the remote past nearly to the beginning of the universe. Open clusters, because of their youth and relative proximity, are excellent examples of star systems in their infancy. Star clusters, pretty to observe from the backyard, are also among the most important contributors of information about stars and their behavior we have.

Gail O. Clark is a frequent contributor to ASTRONOMY whose last article was "Discover the Hyades," in the November 1985 issue. He is book review editor for The Reflector, the newsletter of the Astronomical League.



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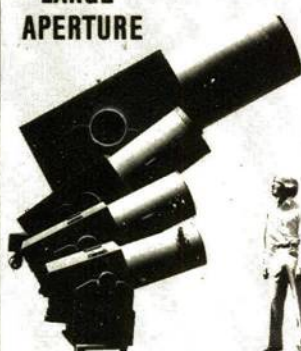
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Viewing Halley This Fall and Winter

Gazer's
Gazette

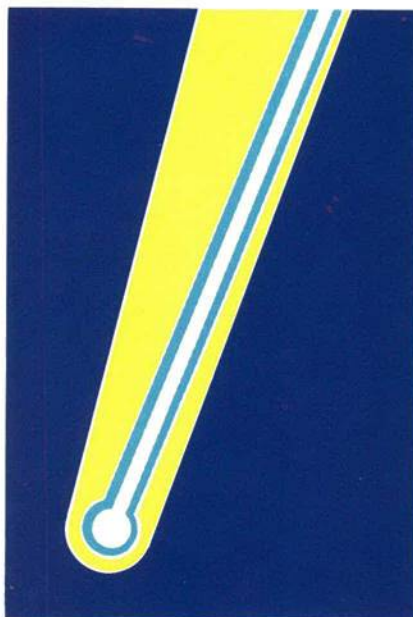
Believe it or not, Halley's Comet is not yet gone. If you have a large backyard telescope and haven't had your fill of Halley's Comet, you still have a little time left to see it. Having moved out of a conjunction with the Sun on September 17, Halley will reappear in October's predawn sky, providing an opportunity for those with larger-than-average telescopes to watch it fade to invisibility.

Having slowed in its graceful eastward arc across the sky, Halley lies in the inconspicuous constellation Crater the Cup (it's actually a goblet with a stem) in October and throughout this winter. Crater's brightest star glimmers at only 4th magnitude, and since the other "prominent" luminaries in Crater are 5th- and 6th-magnitude stars, you'll need a dark sky to be able to see it.

Start at Corvus the Crow, a trapezoid-shaped collection of four bright stars visible under nearly any sky. Look 10° northwest from Corvus to pick out the individual stars forming the bowl of Crater's cup, a semicircle consisting of six stars of magnitudes 5 and 6. The northernmost star is Theta (θ) Crateris and the others are, going clockwise, Epsilon (ϵ), Delta (δ), the double star Gamma (γ), Zeta (ζ), and Eta (η). Halley lies between the two northern stars, Theta and Epsilon, in the C-shaped asterism.

Study the area and memorize the patterns of faint stars visible in binoculars or your finder scope. Once you're familiar with Crater, you're ready to hunt down the faint speck of light that is Halley's Comet.

At the beginning of the month Crater rises shortly before morning twilight interferes with observing. Be prepared to work quickly if you want to see the comet. You'll have to find Halley early in October, however, since the Full Moon becomes a serious hindrance after the 17th. Although Halley's brightness is difficult to predict, on October 1 the comet should glow feebly at about magnitude 12.5. It will be like a tiny, circular patch of gray light about 1° northeast of the star Epsilon in Crater's cup.



The tick marks shown on the map on pages 116 and 117 are 0h Universal Time for each day shown. Universal Time is the 24-hour, unambiguous time system astronomers use to accurately record the times of events. You will have to convert the local civil time at your observing location into UT and interpolate the comet's position on the map. If, for example, you observe the comet at 6h UT on October 5, then the comet will lie one-quarter of the way between October 5 and October 6.

Be careful when you scan in the area of the comet, since three galaxies will be in the general area. To avoid confusion, check where these galaxies lie in relation to the comet on the night you observe. On October 1 NGC-3672, a 12th-magnitude Sb-type spiral, lies 1.5° northwest; NGC-3637, a 13th-magnitude barred spiral, lies 3° west; and NGC-3732, a 13th-magnitude elliptical, lies 2.5° northeast. NGC-3672 is 3.5' in diameter and elongated, but the other two are round galaxies. All might approximate the magnitude of

Halley at the time and, consequently, are a potential source of confusion.

Halley's brightness should stay almost constant during October, dropping only by a few tenths of a magnitude during the month. Halley's motion on the sky will be slow. It is moving south-southeast. Once you have found Halley one night and know what it looks like, it should be easy to find again.

By October 10 the comet will have moved about 2° from its position of the 1st. By October 20 Halley will have moved another 2°, forming a right triangle with Epsilon and the double star Kappa (κ) Crateris. The Full Moon, however, will make it difficult to see.

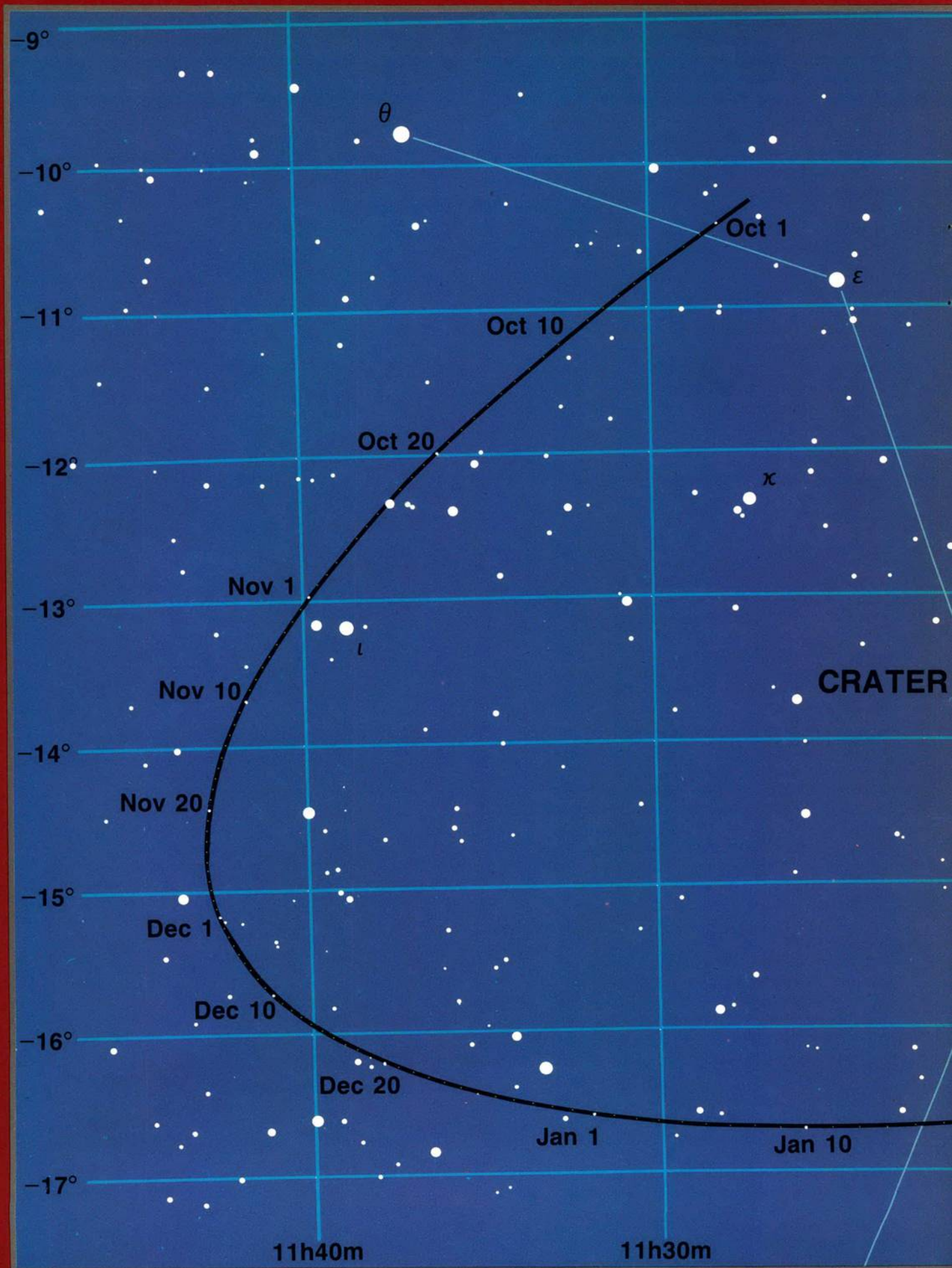
During November and December the comet continues moving through a loop to the south and slowly curves southwest, passing 2° west of the double star Iota (ι) Crateris during the middle of November. Throughout December Halley will slowly arc southwest and may glimmer at about magnitude 13.5. By January 1 the comet will form an equilateral triangle with the bright stars Gamma and Delta Crateris near the base of Crater's cup.

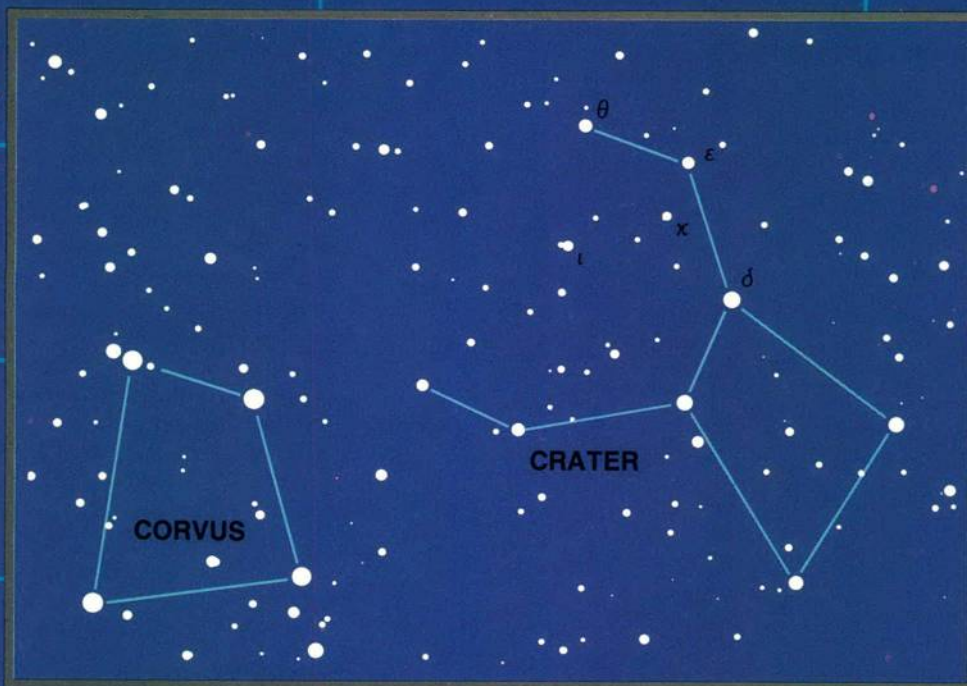
Zeroing in on Halley should be relatively easy once you're familiar with the area. The map shows stars as faint as magnitude 9.5. Starhop from Theta to Epsilon to get a feeling for the scale of the view in your telescope's eyepiece, then starhop to the field containing Halley. You should see a small, fuzzy blob of light among a field full of faint, pinpoint stars. The fuzzy blob is Halley.

On one of the first clear nights in October, rise early and make an effort to see Halley as it fades into the dark depths of the solar system. At 13th magnitude it may not impress you as it did back in March, but the chance to see this famous comet journey along its long orbital path toward aphelion is a privilege backyard star gazers haven't had before.

And who knows, if you follow the comet loyally, you may see Halley fade away before your eyes!

— David J. Eicher

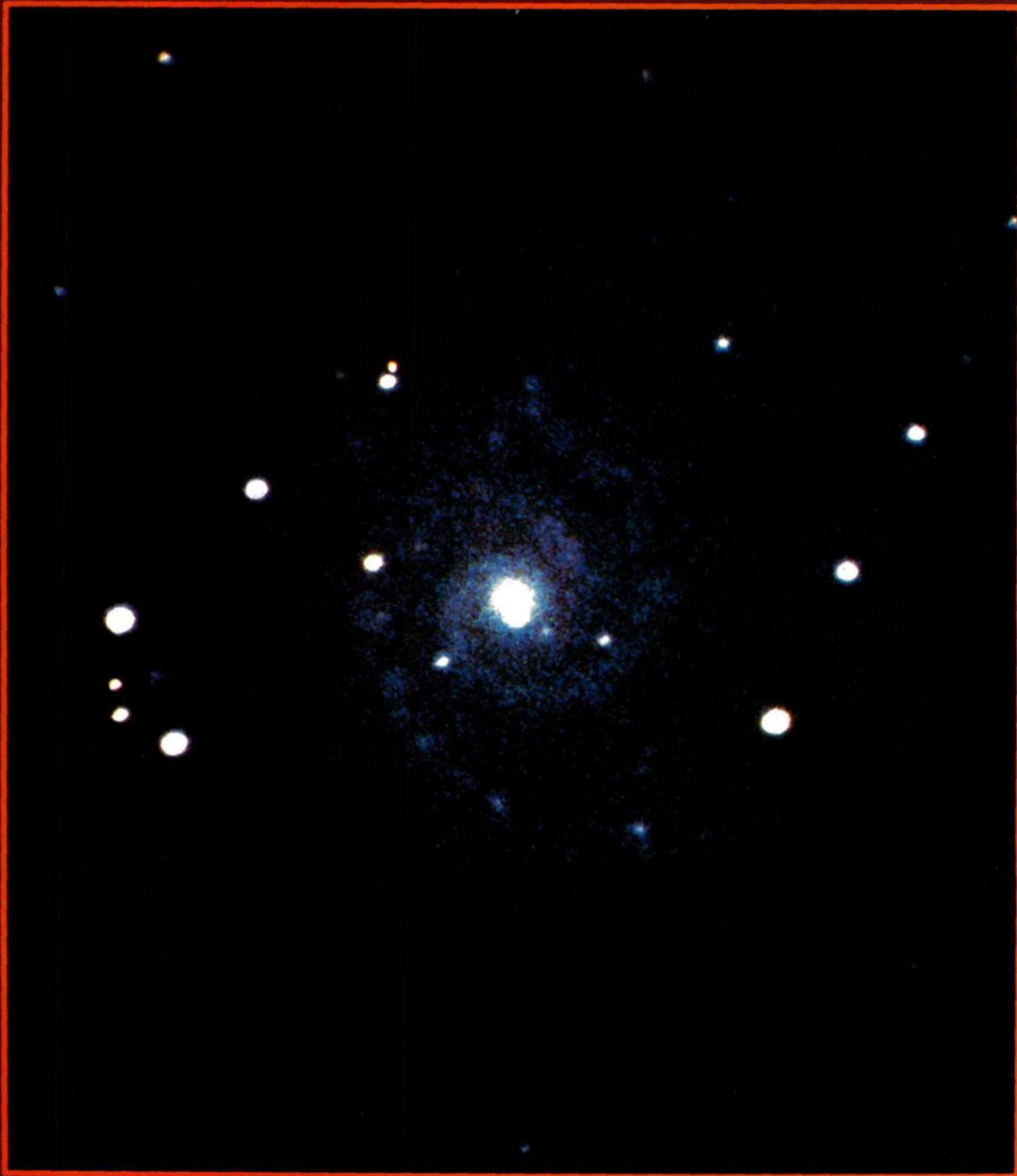




Halley's Receding Path

The position of Halley's Comet is shown at 0h UT on the dates listed on the map. The position marked "Oct 1," therefore, approximates Halley's position during the evening of September 30 and the morning of October 1. Between October and February Halley moves through a section of the constellation Crater. The inset map shows Crater along with Corvus, a much brighter group of stars. To zero in on Halley, first find Corvus and then move to the region of Theta (θ) and Delta (δ) Crateris. Map by David J. Eicher and Richard Berry.





Although it has a relatively low surface brightness, M-74 is one of the best examples of a face-on spiral in the sky. Under a dark sky, a 6-inch telescope reveals a subtle arm structure. Photo by Bill Iburg.

Pisces

Psc

Piscium

Situated between Pegasus and Cetus in the barren star fields of autumn is the dim, winding constellation **Pisces** the Fish. Pisces lies far enough from the plane of the Milky Way that it contains no bright deep-sky objects that are part of the Galaxy, except for a few double and variable stars and one of the brightest white dwarfs. Instead, Pisces is inhabited by galaxies, quite a few of which are bright enough to be viewed with backyard telescopes.

The finest galaxy in Pisces is undoubtedly the face-on Sc-type spiral **M-74** (NGC-628). Lying 1.5° east-northeast of Eta (η) Piscium, M-74 is one of the best examples of a face-on spiral in the sky. M-74 is bright but its light is spread out over its large angular size such that it suffers from a low surface brightness. It shines at 9th magnitude and covers some $10.2'$ by $9.5'$. A 3-inch telescope at 50x shows a bright, round, featureless patch of nebulosity some $3'$ across. An 8-inch scope shows a central hub surrounded by a faint $8'$ -diameter halo of nebulosity — the galaxy's spiral arms. On very dark nights, larger telescopes — especially those over 12-inches in aperture — show some subtle detail in the arms, strongly hinting at their spiral nature. Don't be discouraged if you have trouble locating or observing M-74 at first; it has a reputation, due to its low surface brightness, as being one of the most difficult Messier objects.

Discovered by Pierre Mechain in September 1780, the galaxy was sighted again by Messier a month later. Mechain's notes on M-74 described it as a nebula that "contains no star; it is fairly large, very obscure and extremely difficult to observe. . . . One can make it out with more certainty in fine, frosty conditions." M-74 has an unusual observational history behind



Keith Ward

it because of a mistake made by John Herschel in his *General Catalogue*, published in 1864. In it Herschel inexplicably classed M-74 as a globular cluster, a mixup carried over into the *New General Catalogue*. M-74's spiral structure had been observed as early as 1848 by Lord Rosse in Ireland.

Following an imaginary line drawn from M-74 through Eta and continuing another 4° southwest you will find another nearly face-on Sc spiral, **NGC-514**. This galaxy glows at magnitude 11.9 and spans only $3.5'$ by $2.9'$. It looks like a large planetary nebula when viewed with a small telescope. A 3-inch scope shows only a $1'$ -diameter, uniform disk of light dimly glowing with a pale gray hue. A 10-inch telescope reveals a moderately bright center surrounded by a $3'$ -diameter, slightly oval halo of very faint nebulosity. With this aperture there is still no detail to suggest spiral arms.

Some 8° south of the NGC-514 area lies a trio of bright galaxies, each of which is a worthwhile sight in backyard telescopes. **NGC-470**, lying just 1° southwest of the 5th-magnitude star 89 Piscium, is nearly identical in appearance to NGC-514. It glows at magnitude 11.9 and is slightly smaller at $3.0'$ by $2.0'$, but viewed with a small telescope it offers the same slightly oval, plain disk of gray light as that of NGC-514. Within the same low-power field of view is the diminutive galaxy NGC-474, a 13th-magnitude lenticular

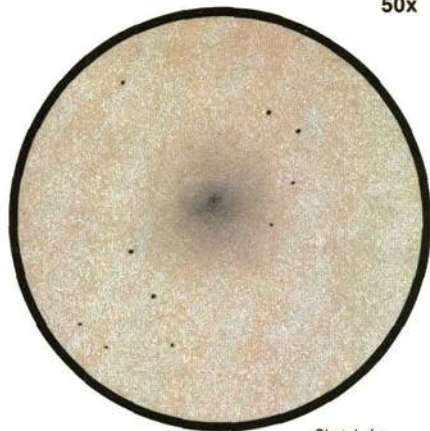
measuring only $0.4'$ across.

About 1.5° northeast of the NGC-470/NGC-474 pair is the peculiar galaxy **NGC-520**. This is one of the strangest, most contorted objects in the sky. In photos made with large telescopes, NGC-520 appears twisted around itself, with streamers and wisps of material trailing outward in nearly every conceivable direction. Astronomers believe that an enormous gravitational influence has shredded the galaxy into the bizarre form we see.

NGC-520 glows at magnitude 11.2 and covers some $4.8'$ by $2.1'$ of sky. Small telescopes show it as an irregular patch of faint light some $3'$ by $1'$ in extent, looking like a normal edge-on spiral. Large backyard instruments, however, show NGC-520 as a different entity altogether. A 17.5-inch scope reveals a mottled, $4'$ -by- $1.5'$ nebulosity that is not uniformly illuminated and appears "twisted." This unusual mottled appearance is indicative of NGC-520's peculiar nature.

NGC-488 is the brightest and most easily observed of the Pisces trio. Measuring $5.2'$ by $4.1'$ and shining at magnitude 10.3, this galaxy is a face-on Sb-type spiral. NGC-488's spiral arms are rather faint and diffuse, but the galaxy's central hub has an exceptionally high surface brightness that is unmistakable in any telescope. A 3-inch scope at 50x shows a bright round spot of nebulosity some $2.5'$ across; a 10-inch instrument shows the same bright

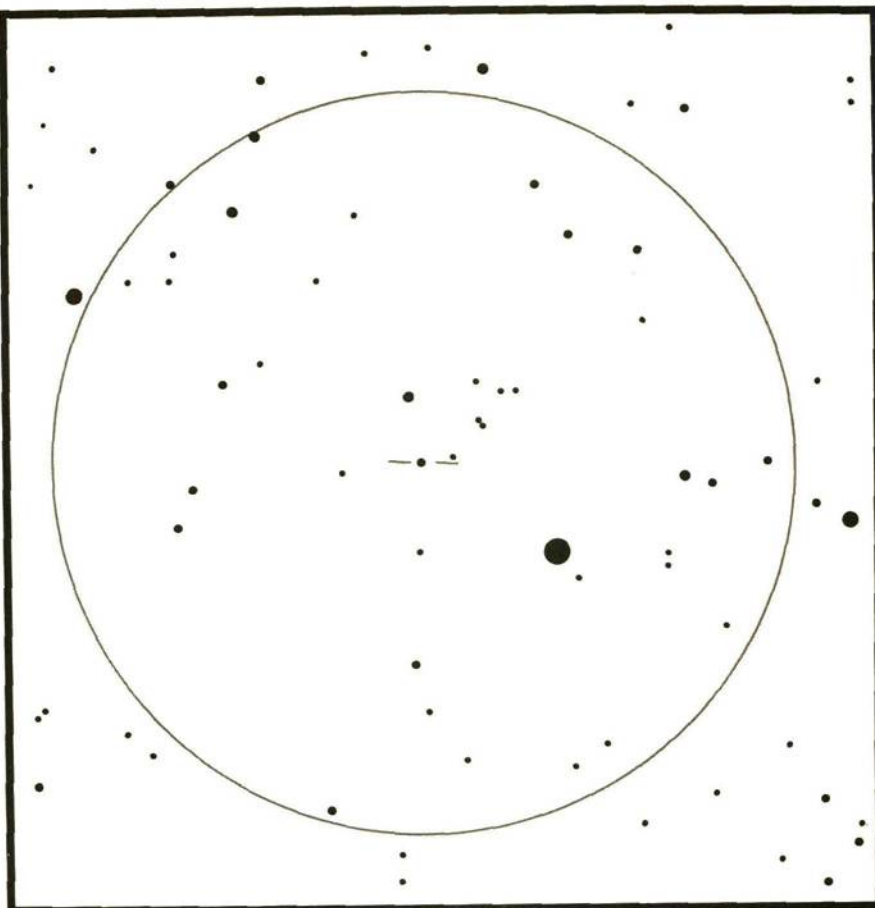
For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

Sketch by
David J. Eicher

disk of nebulosity centered inside a ring of faint light some 4' across. NGC-488 is best observed in a telescope over 12-inches in aperture, when subtle hints of spiral structure appear.

One of the sky's brightest white dwarf stars lies 1.5° southeast of the 4th-magnitude star Delta (δ) Piscium. Catalogued by the famous German astronomer Max Wolf and known contemporarily as **Wolf 28**, this star was identified as a white dwarf by Adrian van Maanen in 1917 and is consequently also known as "van Maanen's Star." With a magnitude of 12.4, this little star — whose luminosity is 1/5,800 that of the Sun — is one of the few white dwarfs visible in backyard telescopes. The diameter of Wolf 28 is about 12,480 kilometers, close to the size of Earth. Its distance is 4.2 parsecs.

Two bright galaxies lie within the central part of Pisces. **NGC-95** is found about 45' southeast of a 7th-magnitude double star; it is a magnitude 12.6, Sc-type spiral measuring 1.9' by 1.5'. This galaxy is faint enough that it appears as a featureless smudge of wispy light in most backyard instruments. NGC-128 lies 2°



The white dwarf Wolf 28, also known as van Maanen's Star, lies in Pisces at 0h49.1m +5°25' (2000). The star dimly glows at magnitude 12.4 and lies in a rather rich field, but this finder chart should enable you to spot it. This circle represents 1°, and north is at top.

northeast of 44 Piscium, just inside the Pisces-Cetus border. NGC-128 is a magnitude 11.6 lenticular galaxy whose size (3.4' by 1.0') gives it a rather low surface brightness.

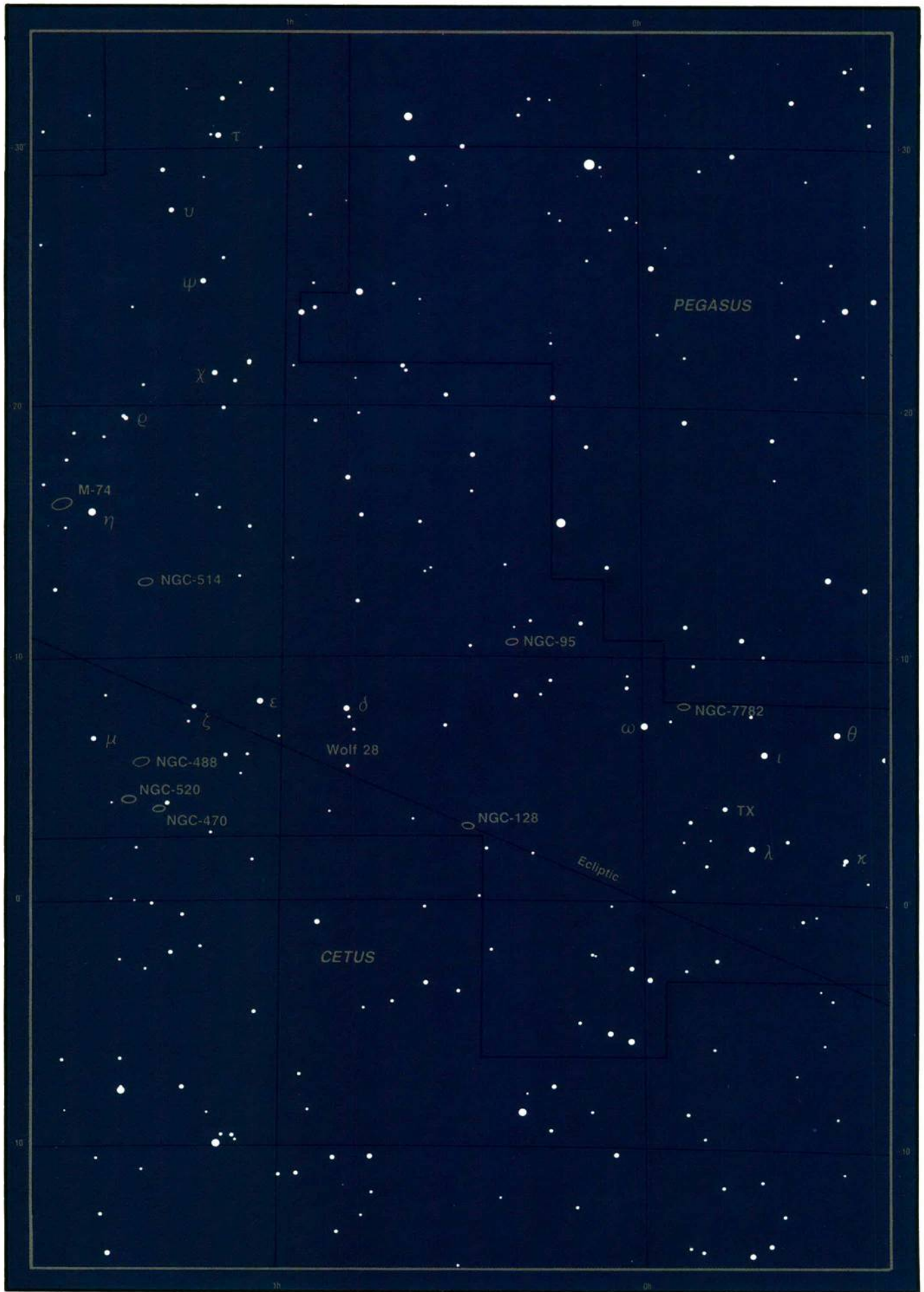
One of several galaxies found in the western part of Pisces, **NGC-7782** is a faint Sb-type spiral located some 3° northwest of the 4th-magnitude star Omega (ω)

Piscium. **NGC-7619** and **NGC-7626** are a pair of ellipticals that lie right on the border with Pegasus and form the core of a remote cluster of galaxies called the Pegasus I Cluster. **NGC-7541** is a 12th-magnitude Sc-type spiral measuring 3.5' by 1.4'. It lies 2.5° northwest of the bright star Gamma (γ) Piscium and is easily observed at low power in a 6-inch scope.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H	
NGC-95		§	0h 22.2m	+10°30'	12.6	1.9'x 1.5'	Sc	★ ² Double Star
NGC-128		§L	0h 22.2m	+ 2°52'	11.6	3.4'x1.0'	S0 pec	★WD White Dwarf
Wolf 28		★WD	0h 49.1m	+ 5°25'	12.4	—		IV Irregular Variable
Zeta (ζ)		★ ²	1h 13.7m	+ 7°35'	5.6, 6.2	23.0''		§ Spiral Galaxy
NGC-470		§	1h 19.7m	+ 3°25'	11.9	3.0'x2.0'	Sc	0 Elliptical Galaxy
NGC-488		§	1h 21.8m	+ 5°15'	10.3	5.2'x 4.1'	Sb ⁻	§L Lenticular Galaxy
NGC-514		§	1h 24.1m	+12°55'	11.9	3.5'x 2.9'	Sc	# Peculiar Galaxy
NGC-520		#	1h 24.6m	+ 4°44'	11.2	4.8'x 2.1'	pec	
NGC-628	M-74	§	1h 36.7m	+15°47'	9.2	10.2'x 9.5'	Sc	
Alpha (α)		★ ²	2h 02.0m	+ 2°46'	4.2, 5.1	1.5''		
NGC-7541		§	23h 14.7m	+ 4°32'	11.7	3.5'x 1.4'	Sc	
NGC-7619		0	23h 20.2m	+ 8°12'	11.1	2.9'x 2.6'	E1	
NGC-7626		0	23h 20.7m	+ 8°13'	11.2	2.5'x 2.0'	E2 pec	
TX		IV	23h 46.6m	+ 3°29'	5.5-6.0	irr.		
NGC-7782		§	23h 53.9m	+ 7°58'	13.1 _B	2.4'x 1.4'	Sb	

H = Hubble type for galaxies

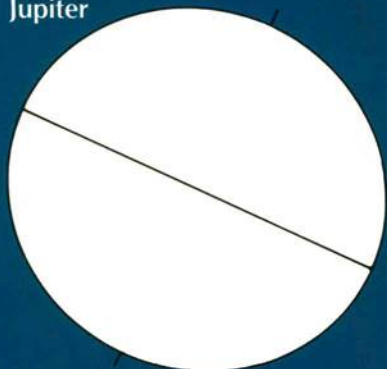
Subscript "P" denotes photographic magnitude; subscript "B" denotes blue magnitude.



Planetary Data

October 1986

Jupiter



Venus



Uranus



Neptune



Saturn



Mars



Mercury

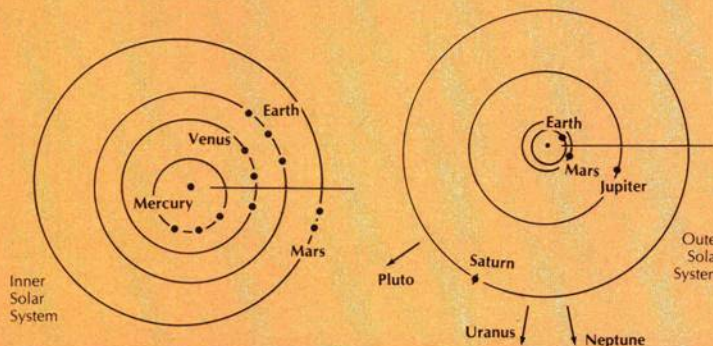


11th



21st

	Date	Mag.	Angular Size	% Illum.	Distance (AU) from:		Longitude:		R.A. (2000.0)	Dec.
					Earth	Sun	Heliocentric	Ecliptic		
Sun	1	-26.7	32.0'	—	1.00	—	—	187°31.7'	12h 28.3m	-3°03.5'
	15	-26.7	32.1'	—	1.00	—	—	201°20.9'	13h 19.6m	-8°23.6'
	31	-26.8	32.2'	—	0.99	—	—	217°16.4'	14h 20.4m	-14°00.0'
Mercury ♀	1	-0.3	5.2"	87%	1.30	0.47	247°34.0'	205°45.7'	13h 34.4m	10°44.5'
	15	-0.1	6.0"	74%	1.13	0.45	286°46.0'	224°52.8'	14h 47.0m	18°36.5'
	31	-0.3	8.0"	39%	0.84	0.38	342°24.5'	238°47.6'	15h 44.4m	-22°45.0'
Venus ♀	1	-4.6	39.7"	26%	0.42	0.73	346°14.1'	226°01.6'	14h 50.0m	-22°28.8'
	15	-4.6	49.9"	14%	0.33	0.73	8°29.5'	230°16.5'	15h 04.6m	-24°29.1'
	31	-4.2	60.5"	2%	0.28	0.72	34°01.5'	225°50.7'	14h 46.9m	-22°25.9'
Mars ♂	10	-0.8	12.6"	86%	0.74	1.38	347°32.4'	300°45.7'	20h 14.6m	-23°01.9'
	20	-0.6	11.6"	85%	0.81	1.39	351°19.9'	306°28.1'	20h 38.2m	-21°16.8'
Jupiter ♃	15	-2.8	47.5"	100%	4.14	4.97	350°57.6'	344°10.3'	23h 03.9m	-7°36.1'
Saturn ♄	15	0.6	15.5"	100%	10.68	10.01	250°40.5'	246°48.4'	16h 20.9m	-19°53.1'
Uranus ♅	15	5.7	3.6"	100%	19.68	19.17	261°51.51'	259°32.6'	17h 14.3m	-23°07.9'
Neptune ♆	15	8.0	2.2"	100%	30.54	30.24	275°05.4'	273°29.9'	18h 15.0m	-22°21.2'
Pluto ♇	15	13.8	0.1"	100%	30.63	29.71	217°11.3'	216°51.2'	14h 38.7m	1°16.6'



Moon Data

New Moon.....October 3 at 18h55m
 First Quarter.....October 10 at 13h28m
 Full Moon.....October 17 at 19h22m
 Last Quarter.....October 25 at 22h26m
 New Moon.....November 2 at 6h02m
 First Quarter.....November 8 at 21h11m
 Perigee: Oct. 7 at 9h52m.....367,199 km
 Apogee: Oct. 23 at 5h38m.....405,074 km



One of the most stunning features of the Milky Way is the Coal Sack, a dark nebula in Crux. This photograph, made with a 50mm f/1.8 lens and a 5-minute exposure, shows it and the surrounding star fields. Photo by Jack Newton.

Mercury

Mercury reaches greatest eastern elongation from the Sun in the evening sky on the 21st, but at that time the planet's declination is so southerly (-20°) that it glimmers only 1° above the western horizon (45 minutes after sunset). This appearance of Mercury is one of the most difficult to observe for the entire year; the apparition in the morning sky late in November, however, will be the year's best.

Venus

Like Mercury, Venus is very low in the west after sunset. Despite reaching greatest brilliancy (magnitude -4.6) on October 1, Venus will be out of view this month for telescopic viewers, unless you observe during daylight by offsetting from the Sun.

The technique is simple with an equatorial mounting and setting circles. Take the positions given on the Planetary Data page and work out where Venus lies relative to the Sun, interpolating for dates other than those listed. Then *carefully* center the scope on the Sun (using eyepiece projection or an over-the-aperture solar filter). Note the coordinate readings and then offset the scope the right amount for Venus. When you reach where Venus should be, remove the solar filter. A moment's scanning with a low-power eyepiece should reveal a large, thin crescent Venus. Hold a red photo filter over the eyepiece to darken the sky.

Moon

An annular/total solar eclipse occurs on October 3. The entire total eclipse track lies in the North Atlantic, roughly halfway between Iceland and Greenland. Maximum eclipse begins with the Moon too far from the Earth to entirely cover the solar disk, thus the first part of the eclipse is annular (a ring, or *annulus*, of Sun surrounds the Moon). The Moon then grows slightly in apparent size and briefly covers the Sun completely, creating an almost instantaneous total solar eclipse. (At best, totality lasts all of one-third of a second.) As the Moon's apparent size shrinks again, totality ends and the eclipse reverts to annular.

North Americans will see a partial eclipse with the greatest "bite" taken out of the Sun for observers in the northeastern part of the continent. Viewers along the West Coast south of about 44° north latitude won't see any eclipse at all.

Anyone observing with a telescope should use a safe, over-the-aperture solar filter or project the Sun's image onto a shaded piece of white cardboard. With solar projection, the Sun's heat can "cook" the cement that binds the eye-



Satellites of Jupiter

3h00m UT

1	EJGC		16	EJGC	
2	EJGC		17	JIEGC	
3	JIEGC		18	IJGEC	
4	IGJEC		19	GEJIC	
5	GEJIC		20	GIEJC	
6	GCIJ		21	GJIEC	
7	CGJIE		22	IJCG	
8	CEJG		23	ECJG	
9	CEJG		24	CJIEG	
10	CJIEG		25	CIJGE	
11	CIJE		26	CGEJI	
12	CGEJI		27	CGIEJ	
13	GCIEJ		28	CGJIE	
14	GJCIE		29	CIJEG	
15	EJGC		30	ECJIG	
			31	JECG	

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)



Left: Extremely faint to backyard observers and nearly as difficult to photograph are the reflection nebulae IC 59 and IC 63 near the bright star Gamma (γ) Cassiopeiae. Both can be glimpsed in a 16-inch telescope if Gamma is placed outside the field. Photo by Mace Hooley.

Right: Mike Simmons takes this month's \$100 "Best Astrophoto" award with his shot of galaxy M-33 in Triangulum. Simmons used a 12-inch f/5 AstroMak telescope and Fujichrome 100 film.

piece lens elements together, so use an old eyepiece or a non-cemented design, such as a Huygenian.

The total lunar eclipse that follows on October 17 is invisible from the Western Hemisphere but will be observable from many parts of the Eastern Hemisphere, perhaps best from the Middle East and India.

On October 7, the Moon (nearing Full) will occult the 1st-magnitude star Antares in Scorpius. The occultation is visible west of the Rockies and along the Gulf Coast, including all of Florida, though viewing conditions in the Southeast will be poor with interference caused by low elevation, twilight, and the bright limb of the Moon. Times of disappearance range from 19:30 UT in the Northwest to 23:30 in the Southeast. If you live where the event is visible, check with a local astronomy club for more details.

Mars

Mars' visibility to the naked eye may actually improve during this month as it keeps pace with the apparent eastward motion of the Sun and moves several degrees northward in declination. But, for telescopic viewers, the Red Planet is a small, orange-amber dot shimmering in a high-power eyepiece.

On the 1st, Mars measures 13.6" across and is down to 10.6" by the 31st. If you observe carefully with your telescope you will also note that its disk appears subtly flattened. What's happening is that we are glimpsing a small part of its nightside

hemisphere (the part just before Martian dawn). This lends the disk a slightly gibbous look. This month also marks the summer solstice for Mars' southern hemisphere. Look for changes from week to week in the apparent size of the south polar cap as it shrinks under the balmy rays of the Sun.

Minor Planets

1 Ceres is in solar conjunction on November 2 and is out of view all month.

2 Pallas (magnitude 9.0) is moving eastward in central Virgo. Its positions:

1st: 12h 21m 10s, 2° 25.0'

10th: 12h 37m 58s, 1° 45.2'

20th: 12h 56m 28s, 1° 04.3'

30th: 13h 14m 46s, 0° 28.1'

Pallas rises around 6:30 a.m. local daylight time on October 15.

3 Juno (11.3) has an eastward motion in Ophiuchus. Its positions:

1st: 16h 43m 46s, -10° 26.6'

10th: 16h 53m 16s, -11° 08.4'

20th: 17h 04m 45s, -11° 50.7'

30th: 17h 17m 07s, -12° 27.9'

Juno sets around 9 p.m. local daylight time on the 15th.

4 Vesta (6.4) is at opposition in western Cetus on October 3. Its positions:

1st: 0h 57m 32s, -6° 54.3'

10th: 0h 49m 07s, -7° 44.0'

20th: 0h 40m 20s, -8° 21.5'

30th: 0h 33m 09s, -8° 36.8'

Vesta is visible all night long.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star map (*Sky Atlas 2000.0*, for

example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

During October, Jupiter is a pearly white ball at magnitude -2.8; it measures 47.5" across its equator (the polar diameter is 44.4"). Prominent in the southeastern sky after sunset, Jupiter is now ideally placed for telescopic observations. Although Jupiter was closer, brighter, and larger at opposition last month, many people find observing the giant planet is easier a month or two after opposition when Jupiter lies at a good elevation during the evening. At opposition, planets are highest at midnight, an hour that may be too late for those who have to get up early in the morning.

Saturn

Saturn has sunk so low in the southwest that it is all but hopeless to try to observe it with a telescope this month. Although Saturn doesn't reach solar conjunction until December 4, its low declination (-20°) means it will set an hour or less after the Sun. If you observe from a location with a flat southwestern horizon, you may be able to keep it in sight up until the third week of October, but the distorted seeing near the horizon will prevent good views. Early in 1987, Saturn will reappear in the morning sky just before sunrise.

Uranus

Uranus is becoming hard to observe as its region of sky sets relatively soon after sunset. Using a star atlas and a wide-field finder scope (or binoculars), locate 3.3-magnitude Theta (θ) Ophiuchi. Then with the main scope and a low-power eyepiece sweep 2½° northwest, past the 5th-magnitude double star Omicron ($\omicron$) Oph. Uranus has a 6th-magnitude bluish green disk 3.6" across.

Neptune

One hour of right ascension east of Uranus and higher in the sky, Neptune is smaller and dimmer than Uranus and is located in a more crowded star field. Look for Neptune by centering the finder scope on 3.9-magnitude Mu (μ) Sagittarii. Neptune lies about 1½° due south and has an 8th-magnitude, grayish disk 2.2" in diameter.

A Matter of Choice

Joe Caruso is the chief telescope operator at Wesleyan University in addition to teaching astronomy at the University of Hartford. He uses the 20 inch Alvan Clark refractor to precisely determine trigonometric parallax for stars in the solar neighborhood. With access to some of the world's most sophisticated astronomical instruments, Joe's telescope of choice is the Bausch & Lomb 4000 for leisure time observing. The 4000 incorporates the quality and many features found in larger telescopes. From his home in the city, Joe reports no difficulty acquiring the 12th magnitude G8 subdwarf in the Pleiades. In addition to the fine optics and mechanical aspects of the 4000, Joe considers the portability a very useful feature.



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18\$149
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